

Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

aSD11
.A32
RESERVE

U. S. DEPT. OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY
AUG 31 1966
C & R PREP

FORESTRY RESEARCH PROGRESS IN 1965

McINTIRE-STENNIS COOPERATIVE FORESTRY RESEARCH PROGRAM

COOPERATIVE STATE RESEARCH SERVICE

U.S. DEPARTMENT OF AGRICULTURE

TABLE OF CONTENTS

		<u>Page</u>
INTRODUCTION		1
	<u>Progress Statement No.*</u>	
FOREST BIOLOGY		
Soils and fertilization	1 - 15	2
Physiology	16 - 39	12
Ecology	40 - 45	23
GENETIC IMPROVEMENT		
Variation and selection	46 - 54	26
Breeding	55 - 67	29
SILVICULTURE		
Seed, regeneration	68 - 72	34
Timber stand improvement, thinning	73	35
Specialty products	74 - 77	35
Special plantings	78 - 81	35
FOREST PROTECTION		
Fire	82 - 84	38
Pathology	85 - 94	38
Entomology	95 - 110	42
FOREST MANAGEMENT		
Timber Management	111 - 114	46
Mensuration	115 - 125	47
Site	126 - 130	49
Aerial techniques, survey	131 - 134	51
Recreation	135 - 151	52
Wildlife	152 - 160	56
Range	161 - 166	59
Watershed	167 - 171	60
Multiple-use	172 - 176	61

* Each progress statement begins with a serial reference number. The inclusive numbers are shown. Serial numbers are also grouped by university in the Index, p. 85.

TABLE OF CONTENTS (Cont'd)

		<u>Page</u>
FOREST UTILIZATION		
Logging	177	64
Wood properties	178 - 206	64
Manufacture, design	207 - 213	74
Seasoning, preservation	214 - 217	76
Pulp, composite products	218 - 222	77
FOREST ECONOMICS		
Policy	223 - 231	80
Marketing forest products	232 - 240	82
INDEX OF UNIVERSITIES AND THEIR STATEMENTS OF PROGRESS		85
PUBLISHED RESULTS OF McINTIRE-STENNIS RESEARCH		88
PROVISIONS OF THE ACT AUTHORIZING THE McINTIRE-STENNIS PROGRAM		95
MAP SHOWING LOCATIONS OF PARTICIPATING INSTITUTIONS- - - - -		inside back cover

FORESTRY RESEARCH PROGRESS IN 1965

McINTIRE-STENNIS COOPERATIVE FORESTRY RESEARCH PROGRAM

Introduction

The McIntire-Stennis Cooperative Forestry Research Program (Public Law - 87-788) was started with an initial appropriation of \$1,000,000 on December 30, 1963. One hundred ninety-five research projects were undertaken at 59 institutions in the 50 States and Puerto Rico. For the 1966 fiscal year, beginning July 1, 1965, the appropriation was increased to \$2,500,000 and research is active today in some 240-odd projects. The number of research projects was not increased in proportion to the increase in funds since additional financing was necessary to bring many of the initial projects up to a level needed for progress at a desired rate or scale.

This second national report of research progress in the new program largely speaks for itself as to the degree of accomplishment over a short period, the variety of problems under study and their importance, and the quality of effort. As is evident in statements of progress, the program is increasingly an excellent vehicle for the accomplishment of research toward solution of problems which have recently received national attention, in view of their urgency.

The statements of research progress were supplied by the Forestry Representatives of the participating institutions. The progress in 1965 reported in the seven major forestry research fields totals as follows:

Forestry Research : Field	Progress : Statements	Publications, Theses, : and Manuscripts in Process	Graduate Students : Receiving Research Training
Biology	45	18	40
Genetics	22	4	23
Silviculture	14	3	13
Protection	29	18	27
Management	66	25	98
Utilization	46	20	52
Economics	18	9	20
ALL	240	97	273

The number of graduate students receiving research training and experience through their participation in McIntire-Stennis projects increased from 164 in 1964 to 273 in 1965. The proportion of individuals listed as project leaders in 1964 who had earned the Ph.D. degree was 69 percent, and much the same proportion continues. Not a few of the project leaders are among the foremost investigators in their specialized fields of research.

FORESTRY RESEARCH PROGRESS IN 1965

McIntire-Stennis Cooperative Forestry Research Program

FOREST BIOLOGY

SOILS AND FERTILIZATION

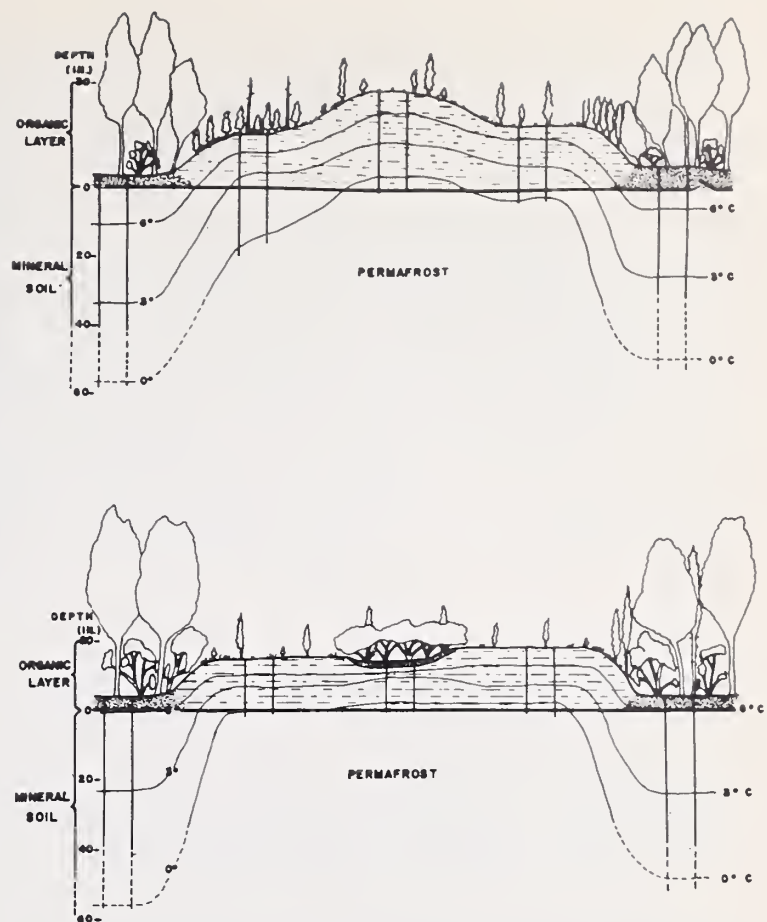
Advances in 15 projects are contributing much to our understanding of important ways in which soil characteristics--including moisture and nutrient levels, physical features, the addition of fertilizers and other factors--influence the growth and composition of forest stands and the quality of wood being formed in the stems.

(1) At the Hawaii Agricultural Experiment Station, there is much interest now in the effects of the soil properties upon the growth of the introduced hardwood species which have been growing in trial plantations for many years. Native species are generally poor timber producers. Australian redcedar (Toona Ciliata) and flooded-gum (Eucalyptus saligna), another Australian species, have been selected. Growth rate of both species varies much depending upon the soil type, and on some soils plantations have failed to survive. On the best sites the timber is of good quality and the growth in board feet per acre annually may go as high as 1,200 for Australian redcedar and 3,800 for flooded gum. Toona is being extensively planted now. In research already completed for this species, soil factors found to have significant effects upon tree growth include aggregate stability, available water, field-moisture content and long-term potassium reserves. This information will be useful in future selection of planting sites. Further relationships are being studied by computer analysis and these are expected to make possible quantitative predictions of growth, depending upon the soil characteristics.

Jumping next to the relations between soil and forest growth in interior Alaska, the problems of interest are strongly contrasting.

(2) The University of Alaska has studied soil temperatures in relation to the growth of spruce. Figure 1 shows how temperature depends upon the thickness of the sphagnum moss accumulation. On the southern slopes of hills, the soils are warmer than on north slopes in August, but if there is a dense stand of mature white spruce the soil is markedly colder than where such a canopy is not present, and the rate of height growth is very much less. On north slopes productive forests are converted to sphagnum bogs by a process in which the interaction of soil temperature and soil nitrogen is of importance.

Fig. 1 - University of Alaska project 2-0236B. With heavy accumulation of sphagnum moss under mature white spruce stands, summer temperatures of upper soil layers are low and height growth is much reduced.



Sphagnum bogs can occur on slopes as steep as 50 percent and productive birch stands often occur adjacent to them, apparently for the reason that the sphagnum has been burned, thus greatly changing the soil and the tree growth resulting.

(3) At the Mississippi State University, thorough and extensive analyses are being made of soils which support coniferous forest in the state. All physical and chemical analyses have been completed for each of 100 sample areas and the measurement data for 16 separate soil characteristics have been summarized by successive soil horizons. This information is needed for correct classification of important Mississippi forest soils, under the new Comprehensive Classification System.

(4) Investigators at the University of Illinois studied soil originally developed under prairie conditions but now supporting old-growth natural forest which first became established 400 to 600 years ago. Where internal drainage is poor the change to forest vegetation has not yet altered some of these soils very much. Differences between the original prairie soil types have had a marked influence upon the composition of forest-tree species which have developed on them--mixed hardwoods on one poorly-drained type (Brunizems) and sugar maple predominating on another (Brunizem-Grey Brown podzolic intergrades). Comparing shrubs in forest stands--mainly pawpaw and spice-bush--this kind of vegetation was prominent on Humic Gley and Brunizem soils, but decreased sharply on the better drained intergrade types.

(5) At the University of Montana, serving a region where little is known about the forest soils, studies are also being launched on how a specific soil factor--available soil moisture--affects not only the species composition of forest, but also the amount of wood produced, root-flowering-seed production habits and even the animal groupings within the forest environment. A second objective is to discover how forest management practices such as logging, slash burning and grazing affect forest soils and the organisms they support. Current efforts are aimed at finding better methods of analyzing the plant and animal populations so that knowledge of them can be related effectively to the underlying soils and soil organisms. A third objective is to reconstruct the history of different kinds of plant communities which have occupied, successively, a given location by examining the tiny and indestructible "opal phytoliths" left behind in the soil after the plants have decayed. Figure 2 shows one form of these phytoliths, from ponderosa pine, under a microscope. Different species of plants have each produced highly characteristic shapes of opal phytoliths within their tissue. Finally, the University of Montana researchers are attempting to develop recognition standards for soil mineral deficiencies in major Montana forest species. In initial work with western larch, the aim is to develop diagnostic guides for detecting soil deficiencies of nitrogen, phosphorus, potassium, calcium and magnesium.

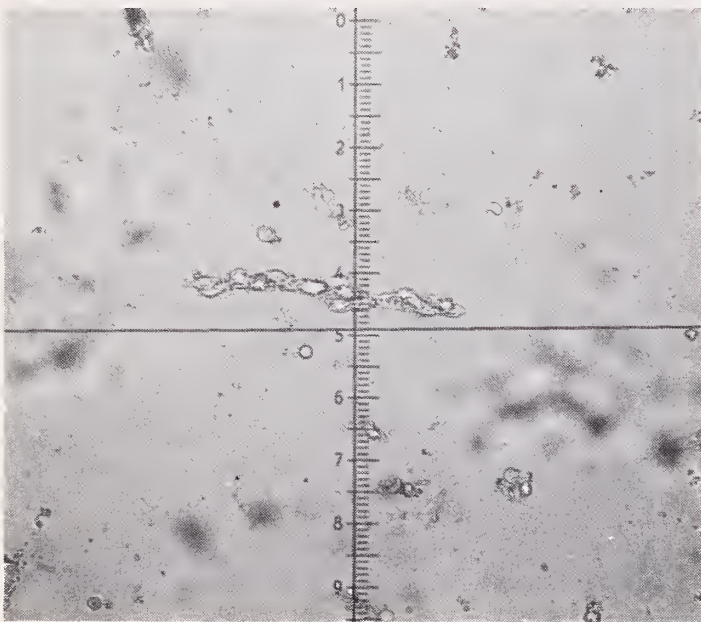


Fig. 2 - This particular opal phytolith retrieved from the soil, 150 microns in length, is of a characteristic shape which shows it was deposited originally in the tissue of a ponderosa pine needle. Opal phytoliths of various shapes and sizes found at successive depths in the soil are being studied as clues to the species composition of former vegetation.



Fig. 3 - Forest scientists and graduate students at the field laboratory of the University of Montana, School of Forestry. At extreme left is Dean Arnold W. Bolle, Administrative-Technical Representative for the McIntire-Stennis program at this institution.

Soil moisture is the focus of research in projects at three other institutions. (6) Soil moisture effects on tree growth are being studied at the Illinois Agricultural Experiment Station under controlled conditions in an 18-year-old loblolly pine plantation. In some plots, moisture is added to the soil to keep it near optimum; in others, as shown in Figure 4, the ground is completely covered by plastic sheeting to reduce moisture to very low levels. These contrasting actual field conditions will be especially favorable for revealing the kinds and degrees of effect of soil moisture deficiency upon diameter growth, height growth and the number of growth "flushes" during the growing season. Volume growth differences are now being computed.

(7) At Humboldt State College basic forested watershed research has been initiated on two creek watersheds in the section of northern California where recent flooding resulted from heavy rainfalls. Vegetation has been mapped and sampled and some of the instrumentation installed to study fundamental relationships between the natural forest cover, stream flow, and soil moisture on a virgin watershed.

(8) At the University of Georgia the objective is to determine variation in hydrologic conditions under different forest cover types occurring on an upland Piedmont soil. Soil sampling for four characteristics is well underway.

At two institutions, forest soil scientists have wanted to learn more about how the mycorrhiza influences the growth of forest trees. Mycorrhiza is the name given to a remarkable growth partnership which many trees make with thready soil fungi in their fine roots. The trees are known to benefit by receiving the soil moisture and dissolved nutrient chemicals which the fungi absorb and pass into the tree roots.

(9) The progress made at Cornell University is given in the following account.

"Soil fumigation has been an unpredictable tool in managing sandy nursery soils in New York. The results are often spectacularly good: weed seeds are killed, soil insects and diseases controlled, and growth of the young trees is stimulated. But occasionally the results are spectacularly bad; though weeds and pests are under control, the seedlings become purplish and stunted, and over-wintering losses are high."



Fig. 4 - University of Illinois project 55-360. Sweeping up needle fall from a plot being maintained under severe drought conditions. Rain is prevented from reaching the soil by covering entire plot with plastic sheeting and sealing it tightly against tree stems. Access tube for measurements with a neutron soil moisture meter is in the background.



Fig. 5 - Oklahoma State University project 1238. The best height growth of these shortleaf pine seedlings growing on major soil types was found to correspond to the best development of mycorrhizae on the roots.

"We found that after heavy fumigation the seedlings do not have mycorrhizae. Apparently fumigation eliminates the beneficial mycorrhizal fungi along with certain harmful ones. Without mycorrhizae the seedlings absorb little or no soil phosphorus and without this essential element they remain stunted and purple. This damage can be offset either by re-introducing the necessary fungi after fumigation or by heavy application of phosphatic fertilizer. The combination of fumigation, fertilization and introduction of fungi was better than any single kind of treatment, on the average, and often produced seedlings two or three times as large as untreated soil or after fumigation only. After observation of our first season results both state nurseries in New York have begun pre-sowing applications of phosphate fertilizer."

(10) At Oklahoma State University, the degree of effect of mycorrhizae on growth of seeded shortleaf pine is an important factor in efforts to determine whether over four million acres of timber land in the east-central Oklahoma tension zone are biologically suited for conversion to shortleaf pine. Evaluations performed in the third year following direct seeding suggest that only certain soils in this large area--such as the Linker, Hartsells and the better of the Hector-Pottsville Series--are suited for such conversion. Study of excavated root systems of seeded shortleaf pine has confirmed earlier greenhouse studies of shortleaf growth on the same soils, as shown in Figure 5.

In both pot and field studies growth was greatest in those soils in which mycorrhiza development on the tree roots was best. Seedling grade recovery tallies suggest that, of the soils mentioned, only the better Hector-Pottsville soils capable of supporting at least a post oak-blackjack oak-hickory association are biologically amenable to

conversion to pine. Quantitative data now being gathered are needed to establish whether or not conversion of the oak-hickory stand to pine is a better practice in economic terms than conversion to native grass pasture.

When forest soils contain low levels of the chemical elements needed for good tree growth, there may be advantage from the addition of chemical fertilizer. Various aspects of this possibility in different types of forest are being studied in Washington, New York, Tennessee, Hawaii, and Pennsylvania. (11) At the University of Washington findings from 15 years of Douglas-fir forest development following nitrogen fertilization are being compiled. A brief summary of results is reported. Nitrogen application has increased basal area and volume growth of Douglas-fir from 50 to 150 percent. Height growth, seed production, and needle retention are improved with nitrogen addition in the soils and growth environment of northwestern Washington. These results, illustrated in Figure 6, have accrued from 250 field plots, established as long as 15 years ago. All measurements have been put



Fig. 6 - Douglas-fir thinned throughout in 1949 as a 30-year-old low site 5 stand. Prof. Gessel stands on the treatment line facing the one-acre fertilized plot. Fertilizing at 50 pounds of nitrogen initially in 1950, and in each of 10 additional years has developed larger trees. The plot with no fertilizer, on right, has thinner crowns, heavier salal understory, and yellow color.

into a computer program, making it possible to summarize present and future measurements rapidly and efficiently. Response seems to be greater on lower site areas, and a single application is effective up to 8-10 years. Current measurements will make it possible to answer many questions regarding use of nitrogen on Douglas fir.

(12) On certain soils in New York, workers at the State University College of Forestry at Syracuse University demonstrated some time ago that insufficient potassium in the soil reduced the growth of red pine. Now, after correcting such a natural potassium deficiency, they have become interested also in the possible effects of the added potassium on the dimensions of the wood fibers formed, the specific gravity of the wood and the proportions in the wood of its two major constituents-- cellulose and lignin. The **first** results refer to fiber length differences in wood formed before fertilization in four experimental sample trees. More than 95,000 measurements confirmed a predicted system of variations in length of wood fibers in the stem. The distribution determined for fiber length variations in the limbs and roots, however, was previously unknown. The length variation in the limbs resembles that in the stems of the same trees except that the fibers are much shorter than those from comparable positions in the stem. Within the major roots, evidence is presented for the first time that average fiber lengths for wood formed both early in the spring and later in season tend to be high. Length is not strongly dependent upon position within the root, but in any one region of the root there is a wider spread between the lengths of the fibers than in the stem.

From the first measurements of wood formed after potassium fertilizer addition, there was some evidence of a decrease in length of fibers in wood formed early in the spring after fertilization, but no statistical significance could be assigned to this possible difference, based on earliest measurements. Preparations have been made to compare wood specific gravity before and after potassium fertilization, with construction and assembly of components for a C 14 Beta ray recording microdensitometer. The continuous wood density traces provided by this instrument will be matched with the fiber measurements and analyzed to discover any trends associated with the addition of potassium to the growing site.

(13) In a Tennessee Agricultural Experiment Station project, the special interest of the researchers is in the effects of combined high level fertilization with several of the elements required by forest trees, of such fertilization together with irrigation, and of irrigation only. Effects upon hardwood species are being studied both in natural stands and in plantations. In a natural stand near Oak Ridge, with yellow poplars ranging in age from 20-80 years, early indications are

that irrigation moisture increased diameter growth in comparison with growth on non-irrigated plots. Another and very marked effect, shown in Figure 7, was the persistence of leaves on the trees at the end of the growing season for several weeks longer than on non-fertilized trees. The same combinations of treatments were given to trees in plantations of yellow-poplar, northern red oak, sweetgum, and loblolly pine. Early indications are that fertilization increased height growth, especially for yellow-poplar and sweetgum. Detailed measurements were also made in this experiment of soil moisture and rainfall, both in the open and under the forest canopy.



Fig. 7 - University of Tennessee project MS-2. Fertilized yellow-poplars in a natural stand still retain their leaves, late in the fall, after leaves have fallen from unfertilized trees.

(14) Interest is increasing in forest planting in Hawaii, but very little of the basic knowledge is at hand. Workers at the Hawaii Agricultural Experiment Station are therefore seeking to learn effects upon tree growth of using several fertilizer elements in combination on different Hawaiian soils. The tropical timber trees for experimentation there have been selected on the basis of past plantation experience with mostly introduced species. Nitrogen, phosphorus and potassium were added in combination to newly established plantations of four species in amounts per element of 100 to 600 pounds per acre. The same fertilizer treatments were given to all species in two plantations, one at Waiakea and the other on somewhat different soils at Melama Ki. The main results of fertilizer addition at these two locations, mostly showing strong height growth increase, are given in the following summary table.

Height growth of 4 tree species by best NPK treatment of plots

Species	Location	Fertilized		Control Height	Time
		Treat- ment	Height		
		Cwt./A.	inches	inches	Mos.
Australian toora	Waiakea	3-4-2	77	29	11
	Malama Ki	3-4-2	54	42	11
Saligna eucalyptus	Waiakea	3-4-2	77	35	5
	Malama Ki	2-4-1	47	32	5
Tropical ash	Waiakea	2-4-1	102	63	11
	Malama Ki	2-6-2	63	50	11
Slash pine	Waiakea	3-4-2	15	9	11
	Malama Ki	1-4-2	13	10	11

On the basis of these results, the slash pine seedlings are being eliminated and replaced with blackwood (Acacia melanoxylon), an important Australian cabinet wood. Queensland maple (Flindersia) seedlings are also being added to the experiment. Much the same experiment will shortly also be established in two additional locations--one on the Big Island of Hawaii in Hamakua District and one on the Island of Kauai.

(15) At the Agricultural Experiment Station of Pennsylvania State University, scientists want to know what eventually happens to the added nitrogen, phosphorus and calcium taken into the tree following fertilization at the soil surface. Working in hardwood forest, they found that in general the foliage of sampled vegetation increased in proportion to the amounts added, but that there was considerable variation among species. The relationship was strong enough to be statistically significant in white oak foliage for all three elements. In scarlet oak, this was true only for nitrogen. Among the forest shrubs, witch-hazel foliage contained significantly greater quantities of nitrogen and calcium, while teaberry plants contained higher levels of all three elements in relation to nutrients added by fertilization. After one growing season, litter samples from the forest floor contained phosphorus and potassium in proportion to amounts added to the surface in the spring. The surface soil horizon (A₁) retained amounts of phosphorus in proportion to the amount added but did not show increased nitrogen or calcium content. No meaningful relationships could be shown for the B horizon. In closely related experimental work, highly reliable equations were developed for predicting the height and diameter growth of white oak and scarlet oak sample trees without fertilization. These equations will be tested with measurements of actual growth.

PHYSIOLOGY

Solutions to some of the biggest problems in forestry and chances to benefit from opportunity situations in tree growth usually depend heavily upon further delving into the particular life processes that take place within the tree and its response to environment. The need for such further information is recognized in twenty-one projects, embracing a wide range of specific questions in tree physiology.

(16) At Michigan State University, the questions under study are:
(a) whether genetically different tree varieties show any important differences in their ability to absorb nutrients from the soil, and
(b) whether nutrient accumulation is related to growth or pest resistance. Analysis of needles of Scotch pine trees from 122 different seed origins showed significant between-seedlot differences in the amounts of nitrogen, phosphorus, sodium, magnesium, potassium, and boron accumulated. At one of the three plantations studied, there were longer internodes where the nitrogen level was high in the needles; but at another site this relation was reversed. Magnesium content was also associated with rapid growth rate. In addition, there was also a probable relation between nutrient accumulation and early fruiting: the varieties bearing the most cones were low in sodium and high in iron and aluminum. Another Michigan State investigator was curious about sawfly resistance in relation to mineral accumulation. He found that resistant varieties were high in sodium, potassium and magnesium. A third scientist studied the geographical variation in needle nutrient accumulation as revealed by the different seedlot origins of planted European black pine. Trees growing from Corsican seeds were slow-growing and non-hardy in the Michigan plantation; their needle accumulation of phosphorus, nitrogen, sodium, magnesium, iron, copper and boron was also low. But when trees were grown from Spain, their needles were long and their content of sodium, iron, and zinc was high. Trees growing from Turkish seed were low in phosphorus and high in zinc. All varieties, however, were affected equally when nitrogen fertilizer was added.

(17) Another relatively little studied question about accumulation of chemical elements absorbed from the soil into the tree is the proportion of the nutrients which goes, not alone to the needles or leaves, but also to stem, bark, branches, and roots. The University of Maine has carried on some prodigious analytical studies needed to answer this question. Preliminary estimates have been made of the relative amounts of 12 elements occurring in the wood, in the bark, in the portion of the complete tree removed in harvesting, and in the complete tree. Knowing these levels will make it possible to maintain an adequate balance of the nutrient elements in the soil for producing trees at optimum growth rates and volumes per acre. Part of the significance of these results is the use of some of the latest methods of analysis, combining high speed and accuracy, to

survey a very broad spectrum of phenomena. The Maine studies included samples of the wood and bark from eight tree sections as well as the needles or leaves of seven major Maine forest species: red spruce, balsam fir, hemlock, white pine, white pine, white birch, red maple and aspen. All of these samples were analyzed for nitrogen, phosphorus, potassium, aluminum, manganese, molybdenum, calcium, magnesium, zinc, copper, iron and boron. The levels determined were coupled with dry weight information on the component parts to estimate the amount of each element in the complete tree. Pronounced differences both within and between species were discovered and have been reported in the literature.

(18) In a related study also at the University of Maine, one of the questions being asked experimentally is, what factors influencing the productivity of forest sites can be improved. Experiments have started in the greenhouse to evaluate effects of different levels of water, nitrogen, phosphorus and potassium on growth of white pine. At the same time, a field survey has been conducted to determine soil factors influencing growth of spruce and fir. On a well-drained soil series there is indication from 10 sample locations that the factors significantly influencing growth of spruce and fir are percent of sand in the A₂ soil horizon and the percent of soil particles less than 2mm in this horizon. On a poorly drained soil series the significant factors indicated were percent of material less than 2mm in the A₂ horizon and the pH of this horizon.

In addition to the life processes which influence tree growth, forest tree physiologists are trying to learn more about those which affect the development of cones and seeds. This is important information in Florida, for instance, where efficiency in growing southern pine species depends strongly upon early and abundant production of genetically superior seed in seed orchards. (19) At the Florida Agricultural Experiment Station, nitrogen fertilization has increased the number of cones produced by slash pines. In addition some preliminary counts of cones have shown that the east side of the tree produces significantly more cones than the west side. This suggested to the physiologist leading the research an environmental influence upon the internal mechanism whereby compounds formed in needles are combined with root-derived substances which trigger flower bud formation. His next step was to take samples of the living tree tissues involved, preserving the internal constituents of interest in their natural form by a rapid freezing technique carried out in the field at the tree location. This was done with liquid and gaseous nitrogen and dry ice. Special techniques were developed to handle the highly resinous frozen pine tissues. One technique was to use a pre-cooled Wiley (grinding) mill into which the tissue was fed in a liquid nitrogen slurry. After passing through the mill, separate samples of tissue of needles, wood and live bark are treated to

yield (a) water diffusate, (b) an ethyl alcohol extract, and (c) the residual dialyzate. These fractions are now being analyzed chemically and further studies will follow to try to discover what was different within the tree on the east and west sides.

At seven institutions the interest of the project leaders and nine of their graduate students has been drawn to studies of the survival of young trees or to growth of trees under conditions where water, light, or some other significant factor of tree environment is at a critical level. (20) At the Iowa Agricultural Experiment Station, for instance, there has been very poor survival after planting of stock derived from an otherwise very promising fast-growing natural hybrid between bigtooth aspen and white poplar (Populus grandidentata X P. alba). Growing four different clones of this hybrid in controlled environment chambers, the researchers concluded that the poor establishment and survival of field-planted seedlings of the same types was probably not due to the effect of light intensity on photosynthesis under conditions where the seedlings received one-third to one-half of full sunlight. The experimental conditions were also demonstrated to be useful in revealing photosynthetic differences which are valuable in performing early genetic selection among types in a tree improvement program. Differences existed among clones and light intensities in rates of net and gross photosynthesis, but not in rates of dark respiration. Significantly, differences occurred in uptake of CO₂ per unit of photosynthetic tissue (photosynthetic efficiency). While seedling size did influence differences among clones in net and gross photosynthesis, difference in photosynthetic efficiency was the more important cause.

(21) In a somewhat related kind of inquiry, the Connecticut Agricultural Experiment Station is seeking to understand how some tree species of plants survive in the shade, and when the opportunity occurs, succeed to a position in the canopy. A full account of results was reported.

"At first, plants that could survive in the shade were thought to have extraordinary photosynthetic ability in dim light, since to survive in deep shade, leaves must capture more radiant energy by photosynthesis than is respired by the whole plant--root and shoot--during darkness. Investigation has proven otherwise. In bright light, shade-tolerant species certainly fix less--not more--energy and carbon dioxide than intolerant species do. Thus, if these tolerant plants were more efficient in dim light, the two curves that relate the photosynthesis in the two kinds of plants to light would cross. In fact, the curves for tolerant and intolerant species grown in the open do cross. In illumination dimmer

than about 200 ft-c, the tolerant species are slightly more efficient, and the light necessary for the leaf to overcome respiratory losses (the light compensation point) is less than in the intolerant species. The difference seemed too small, however, to be important in survival in the shade. Therefore, we set out to accentuate the difference."

"We have grown shade tolerant species (dogwood, sugar maple) and intolerant species (yellow-poplar, yellow birch, quaking aspen) not only in the open but also under shade tents that decreased illumination by 60 percent. Respiration in the dark and photosynthesis at 70, 120, 325, 900, 1500, and 2500 ft-c were measured for all species, both open and shade grown. We expected that a career in the shade would accentuate the difference in ability to fix CO₂ in dim light. Growing plants in the shade did accentuate the advantage of the shade tolerant. Shade grown dogwood were more efficient than aspen. However, the magnitude of the difference was still too small to be important in survival in the shade. Thus, differences in net photosynthesis in the light do not account for the difference in tolerance to shade."

"In the dark, however, respiration of aspen leaves was one-third greater than that of dogwood. This slower respiration of photosynthetic product in tolerant species may explain why they can persist longer in deep shade than can the intolerant, faster-respiring species."

(22) At the University of Idaho, workers are interested in survival in the field, where Douglas-fir seedlings undergo severe summer drought conditions. One problem was how to study root development of surviving and non-surviving seedlings under these conditions of increasing moisture stress, without disturbing the soil. This was done by developing a highly dependable and durable probe to place radiotracers in the soil at various depth intervals under the planted seedlings, and by then using a counter to tell when roots had penetrated to a given level. Radiotracers revealed that roots of 3-year old Douglas-fir nursery stock (2-1) reached to at least the 24-inch soil depth during the first growing season after outplanting on a competition-free site. Roots of outplanted stock grown for two years in the nursery seedbed (2-0) were not traced below 16 inches. Lateral extension of roots of 3-year old plants was 12 inches at the 16-inch depth, and 6 inches at the 24-inch depth. The 2-year old stock produced roots that extended laterally only 6 inches at the 16-inch depth. It appeared that during the early summer, roots of the older seedlings elongated at a more rapid rate than the younger stock, and were actively growing at a later date in the fall. For a time in midsummer, elongation of roots of both classes of stock proceeded at the same rate. An attempt was made

to determine the relative absorptive activity of various parts of the root systems. Although techniques of sampling are yet to be fully developed, preliminary results indicate that age of planting stock did affect uptake of the tracer. For example, through almost the whole growing season, by far the most active uptake of P^{32} by 2-year old stock took place from a soil depth of 3 inches. Three-year old plants, on the other hand, absorbed as much or more of the tracer from the 8-inch depth as they did from the zone of soil 3 inches deep.

(23) A closely related problem, also concerning survival under conditions of low soil moisture, is being studied at the University of Georgia. The question is whether the application of chemicals to needles of slash pine seedlings may cut down enough on transpiration (water loss) through the needles to increase survival percent. This is a question of immediate importance to nurserymen and forest land owners. The effects of four suppressant chemicals on needle temperature and transpiration have been studied under controlled environments and seedlings have been outplanted for evaluation in several soil types.

(24) A prominent problem for study at the College of Agriculture of the University of Nevada is competition between forest and brush species for the soil moisture under conditions of scarcity, as a major factor influencing land use. The project leader has given a detailed account of results obtained during 1965. The overall pattern of daily water use is broadly similar for Jeffrey pine, white fir, willow, Ribes, manzanita, snowbrush, and mountain mahogany during summer months. The rate of water movement is extremely slow just before sunrise, but increases rapidly to a daily maximum by 2 to 3 hours after sunrise. Peak rates continue until several hours before sunset, and decrease thereafter, approaching the early morning low by two to four hours after sunset. Water use during dark hours is most pronounced in mature pines and firs. Water use during fall differs sharply between species. After shedding of leaves, water use is not detectable for Ribes and willow. Pine seedlings and brush species reach this stage 2 to 4 weeks later, while flow is still detectable in mature pines and firs by late November. It is hoped this information can be used for determining when herbicides are most effectively applied, e.g. at peak daily flow during spring resurgence. It may also be used to help predict influence of converting brush to timber on water yield.

(25) The University of Washington is studying ecological and physiological characteristics of important tree species in the Pacific Northwest which are especially significant in their influence on survival of young seedlings and on growth. Success of true fir regeneration in the Canadian zone on the west slope of the Cascades is apparently related to three factors. Ability to germinate early in the season--sometimes even in snow--a juvenile taproot development, and a stem stiffness that is not easily flattened by debris are features that give ecological advantage to the true firs. Current germination studies on true fir seed have shifted in emphasis from enzymatic relations to the effect of the seed coat on germination through inhibition of water and gas exchange measured by respiration. Preliminary results indicate that in mature Douglas-fir, the stomata in foliage at the base of the crown are more constantly closed than stomata higher in the crown. Also, when lower crown stomata do open during the day, they open later and close earlier than higher crown stomata.

(26) A comprehensive study of the rate of transfer of moisture and heat between soil-plant-air surfaces in hardwood stands is underway at the School of Forestry of the University of Missouri. This kind of investigation is fundamental to determining the water economy of forest communities, understanding the growth processes of trees and measuring site productivity. The information is also highly valuable for water management purposes, in determining soil moisture and runoff. Extensive instrumentation and automatic recording equipment is needed. During the past year a tower has been installed which supports a net radiometer, hygrometer, anemometer, a thermocouple for air temperature, and a rain gauge above the forest canopy; similar sensors are mounted six feet above the ground beneath the canopy. Heat flow discs have been placed beneath the soil surface to determine the energy exchange rate between the soil and the air. A network of rain gauges has been installed. Access tubes for soil moisture measurements by the neutron probe technique are being placed at the present time. Information from the meteorological sensors is to be recorded on tape by an automatic data logger which incorporates a digital multimeter. Field measurements of radiation, wind movement, soil moisture, humidity and other environmental factors will begin this winter.

Research at six institutions is concerned with (a) tracing the movement within the tree of the sugars produced in the leaves during photosynthesis, (b) the conversion of these sugars elsewhere in the tree to new wood cells or chemical substances, or (c) the tree's reaction to the internal movement of pesticide materials.

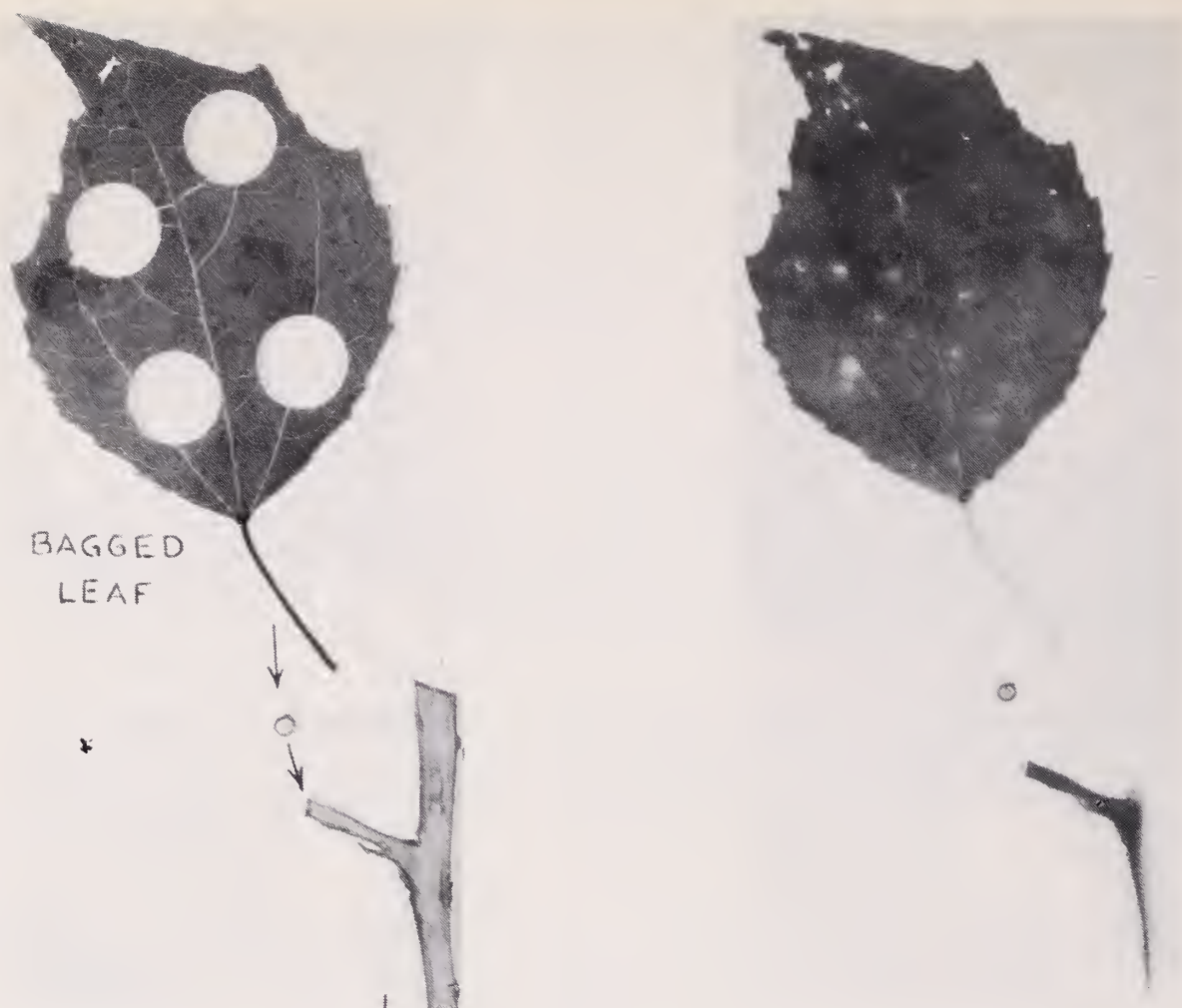


Fig. 8 - X-ray film exposure (right) of aspen twig photographed on left shows black where carbon has been taken into leaf, converted into sugar, and moved out into twig. Movement is clearly only downward, none upward in the twig.

(27) The University of Michigan is trying to find out when newly expanding tree leaves first begin to export sugars, and in which direction within the stem. By a technique utilizing carbon-14 as a tracer in trees in the forest, this study is providing valuable information on the distribution of sugars in trees in their natural field habitats. Photosynthesis fixes C-14-tagged carbon dioxide which is circulated in a bag over individual leaves at various stages of leaf development. X-ray film applied to twig tissues above and below the position of leaf detects the direction, time, and amount of sugars which move from the leaf. Young aspen trees in Michigan utilize all currently photosynthesized sugars in new shoot formation for at least the first six weeks of the growing season. In general all sugars move upwards from new leaves into even younger leaves and new terminal shoots until early July. At that time the oldest leaves shift transport of sugars rather abruptly to a downward direction. In Figure 8 it is clear from the black trace left on the film that the tracer-marked sugar has moved only down into the twig, and not up.

(28) The absorption, translocation and concentration within the seedling tree of tagged nutrients entering from the roots will be traced in a study to begin at Michigan State University when the 1966 growing season starts. Effects of root development and root position will be studied under controlled conditions of varying day and night lengths and temperature. The species selected for study are red and white oak, black cherry, black walnut and Scotch pine.

(29) Fixing attention on where and how much wood growth takes place in a given year in all parts of the stem of red pine, and how environmental factors such as precipitation and fertilization may have to do with this pattern, a research team at the State University College of Forestry at Syracuse University has reported findings which confirm and also extend observations of others.

Maximal ring width in a given year occurs in the upper internodes (in the crown) of a tree. The exact position of maximum ring width, however, varies with the age of the tree, being closer to the stem tip in young trees than in old trees. Factors in environment such as precipitation and fertilization have a pronounced influence on the amount of radial growth in the tree. However, they do not influence or cause a shift in the pattern of ring width distribution in the stem. While the annual growth increment produced following fertilization is larger than the one produced before, the point of maximization remains essentially the same. Also of interest is the fact that fertilization is more effective on trees growing on dry sites than on trees growing on wet sites. This differential response could not be explained on the basis of this study.

(30) Control of low-quality hardwoods is an important activity in southern forestry. Additional knowledge is needed about the effectiveness of chemical herbicides. At the University of Georgia, scientists using radioautographic techniques have traced the transport of active herbicide ingredients in woody plants. "Defense" growths have developed in resistant species to deter the effects of herbicide chemicals. New chemicals and application techniques may arise from this research.



Fig. 9 - Slitting rather than chipping of slash pine may reduce visits by 75 percent without decreasing gum production.

(31) In another University of Georgia project the leader's curiosity centers on the chemical chain of events within the tree which results in production of oleoresins, aspects of the chemical nature of the oleoresins, and techniques for stimulating gum production. Coastal Plain pines yield a bonus product--gum naval stores. Higher gum production will increase efficiency and profits. In this recently begun cooperative project, basic information on the biochemistry of gum production as well as the physiology of storage, production, and transport has been obtained. Techniques for vertically slitting young slash pine have been developed (Fig. 9). This system holds promise for

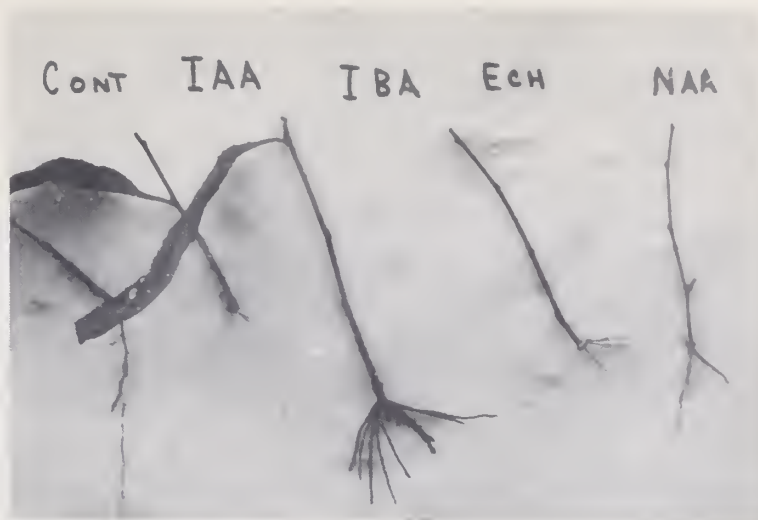
extending gum flow so that re-visits to trees may be cut from bi-weekly to bi-monthly. Extensive field tests of the procedure will be conducted in 1966.

(32) Still another University of Georgia project is designed to determine effects of variation and heredity, environmental factors, and cultural treatments on storage of reserve foods in the roots of pine and hardwood species.

Total carbohydrate content in roots of 12-year-old clones of short-leaf pine has been determined. Statistical analysis within and among clones will enable formulation of conclusions as to the genetic role of food storage in this species. Subsequent research will show how moisture, light, fertility, and season of the year affect food storage in roots.

Four ~~current~~ studies of the life processes of trees are concerned with the very significant objectives of inducing vegetative propagation of trees, or with attempts at successful tissue culture of woody tissues. (33) A project leader at West Virginia University has reported successful rooting (Fig. 10) of cuttings of the high value species, black cherry. They were unable to root twig cuttings from trees of any age regardless of chemical treatment or overwinter precallousing. Cuttings

Fig. 10-West Virginia University project MS-1. Well rooted cuttings obtained from stump sprouts, treated with indole acetic (IAA), indole butyric (IBA) and naphthalene acetic (NAA) acids and ethylene chlorhydrin; control (CONT). Parent trees were 40 years old, cut the year before.



were finally rooted by using one-year-old stump sprouts, from 40-year-old trees felled the previous year. Greenwood cuttings were collected in June and July. Rooting success was enhanced by the use of the instant-dip technique in a saturated solution of indole butyric acid or indole acetic acid (from 11.6 percent rooting for untreated cuttings to 35 percent and 40 percent respectively).

(34) At the University of Maryland, attempts are being made with pine species (also difficult to propagate by rooting stem cuttings) to propagate from needle fascicles (bundles) instead. Fascicles of the current year's growth were successfully rooted for 7 of 8 species of pine with the following rooting percentages: loblolly 9, Scotch 4, shortleaf 7, Virginia 10, red 20, Mugho 21, eastern white 30, and Austrian 35. These percentages are for collections made in March; June and September collections are still under the treatments. Fascicles without buds vs. those with dormant buds induced by previous pruning resulted in a higher percentage rooting for the former condition in every instance. The use of a special propagation chamber utilizing a 24-hour photoperiod with air and rooting medium temperatures at 70° F. under intermittent mist did not improve rooting; in most cases a somewhat higher percentage was obtained with prevailing temperatures under greenhouse conditions, using a polyethylene enclosure with intermittent mist. Hormodin 3 and a sand-peat medium have been used for all treatments. Rootings studies will continue but special emphasis will be given efforts to induce shoot growth. Chemical treatments and different photoperiod and temperature combinations will be initiated. Induction of shoot growth remains the serious difficulty which must be overcome for this method to become important as a means of propagating superior genotypes in forest tree improvement.

(35) A study has been initiated at the University of Georgia to study overall relationships between growth, reproduction and environment for sweetgum, as an aid to developing better guides for management of this

species. Wood and bud samples of sweetgum have been obtained for microscopic examination. Data from a near-by U. S. Weather Bureau station will be coupled with growth performance information to show physiological and environmental relationships.

(36) The objective of a project at the Ohio Agricultural Research and Development Center is to investigate the physical properties of woody plant cells grown in vitro. Callus tissue from hybrid cottonwood continued to grow for several months as a dense white callus on a special nutrient medium in test tubes. Continued efforts will be made to determine the conditions under which wood cells will grow and reproduce under laboratory conditions. (37) On another Ohio project dealing with nutrition of yellow poplar, results are not available as yet. Two additional new projects that will afford training to one graduate student each are too recent for results: (38) on simulated grazing and soil moisture in Utah, and (39) on physiology of phytocide treated woody plants in Alabama.

ECOLOGY

In ecological research there is continuing interest in identifying types of natural forest communities and their extent, as a basis both for better land classification and for improved land management. Partly for the same reasons, ecologists are also interested in the natural process of displacement of one plant community by another ("plant succession") as a contemporary as well as historical phenomenon. In this broad field there are five projects active, and these are contributing research training experience to seven graduate students. Improved ecological understanding is widely recognized as basic to much that is vital in the resource management and conservation field today, and the rate of training of future forest scientists who can deal with ecological problems should be increased sharply.

Current methods of classifying plant communities can be improved if the appropriate data are analyzed by programmed calculation techniques on high speed computers. (40) At Purdue University, basic computer programs have now been written which make it possible to handle data previously impossible of analysis because of its volume and complexity. Methods for programming are being improved at the same time as new ways of approaching the problems of classification are being analyzed.

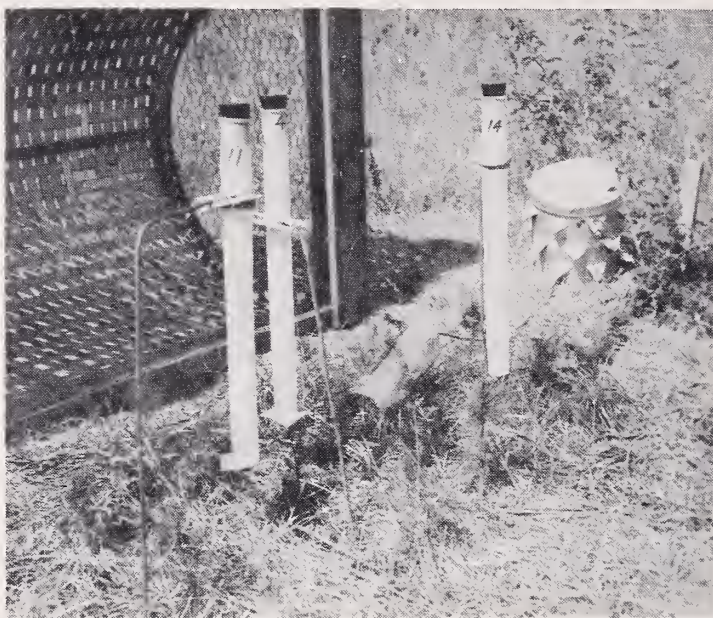
(41) The University of California is pursuing one of the ways toward an answer to the question of the ecological and successional potential of the redwood tree by studying where redwood and Douglas-fir, a redwood associate in some areas, fall on a soil moisture gradient. Redwood seedlings permanently wilt and die when the tension the leaves of plants must exert to obtain water reaches 176 pounds per square inch (12 atmospheres); however, Douglas-fir is able to survive tensions greater than 15 atmospheres for some time. Redwood also appears to be much more sensitive to increasing evaporative stress than Douglas-fir, primarily, perhaps, because of redwood's relatively inefficient regulation of loss of water by transpiration from the leaves. The soil moisture gradient studies so far performed have been (a) where redwood and Douglas-fir grow on upland slopes centered around prairie vegetation and (b) where redwood, Douglas-fir and tanoak occur in alluvial flats.

(42) In a related investigation, researchers at Oregon State University are seeking to identify those specific characteristics of vegetation which enable some species to replace others, and to determine just why some species are successful in dominating other vegetation under the combined influences of plant and animal associates.

(43) In the Siskiyou Mountains, Oregon State University is also trying a new approach to land classification, applying techniques recently developed by plant physiologists to determine directly in the leaves of

plants the suction they must exert to obtain water at critical times. It has long been known that the ability of a particular plant to obtain water during a critical period often explains why one species survives and flourishes, while another dies. Field methods were developed last summer that permit comparison of the advantage that one plant may have over another in certain environmental conditions. It was found that mature Douglas-fir trees often survive under conditions where soil water is so limiting that the needles must exert a suction of as much as 450 pounds per square inch (30+ atmospheres) in order to maintain their internal water balance. The land classification objective is also being advanced through tests developed using controlled condition growth rooms where fertility of soil profiles removed from the field are compared. The range of environments under study in the field (see Figure 11) is being measured by over 25 weather stations scattered over an elevational range of 5,000 feet.

Fig. 11 - Evaporimeters for field environment measurement at one of 25 weather stations in Oregon State University's Siskiyou Mountain land classification project 761.



Earlier in this report (cf 5) we mentioned that phytoliths have promise of use in dating the age of vegetative material laid down at various depths in an accumulation over geological time. Pollen grains in bogs have long served a similar purpose. They are highly characteristic of the plant species which produce them, and are well preserved when they fall into acid bogs. (44) By study of pollen samples from successive depths of bogs in northern Arizona's high plateau areas, Arizona State College is attempting from the pollen deposits to determine past climates and vegetation.

(45) The New York State College of Agriculture at Cornell University is interested in discovering which species significantly increase or decrease in forest stands which have been burned. The study was prompted

by occurrence of an unusual number of wildland fires in 1962, 1963 and 1964, due in part to current drought cycle. Some of these fires have provided the locales for research, in northern hardwood forest, oak forest and open grasslands. Sixteen areas burned in the spring and one in September; all were sampled 12 to 14 months after the accidental burns.

In the northern hardwoods burned areas, fire ruined trees for human use, severely scarring or killing many of them, but created a diversity of habitats for many organisms. Most saplings were killed and usually did not produce basal sprouts; many forbs and grasses from adjacent fields often invaded; and the fires consumed most of the litter and temporarily reduced soil acidity. Fires had occurred at intervals of three to twenty years in the eight oak woods studied. Burning caused a temporary reduction of soil acidity, removal of most of the litter, basal sprouting of most saplings, little tree mortality and few changes in the species of woody and herbaceous plants. In the absence of fire these oak stands change slowly to northern hardwoods.

Among the grasslands there were some sharp differences. Four of the six burned open grasslands contained much poverty grass, bluegrass and goldenrod. The other two grasslands had abundant little bluestem, which after fire produced a greater weight per unit area than the bluestem on the unburned control, while the combined weight of forbs and woody shrubs decreased. Fire killed completely only a maximum of one-fourth of invading saplings. Therefore, abandoned open lands will evidently return to forest in spite of infrequent accidental fires.

GENETIC IMPROVEMENT

There is now wide recognition that for growing timber efficiently and of high quality, and to meet the production demands of the future from fewer acres we will need to develop genetically improved varieties of forest trees. At some institutions, genetic tree improvement programs have been underway ten years and at others they have begun recently. Most of them involve a high level of activity. The volume of wood grown per acre, the form of trees, quality of their wood and ability to resist damage from diseases, insects, animals and extreme climatic conditions are the overall objectives for genetic tree improvement. This field of research is well activated under the McIntire-Stennis program. It extends to all the major forest regions, and at a half dozen institutions it is contributing to the training of future forest geneticists. It will be convenient to describe the current research under two headings: Variation and Selection; and Breeding. Genetics research which majors in the variation and improvement of wood properties is not described here, but in the Wood Properties section, under Forest Utilization.

VARIATION AND SELECTION

In the South two studies are designed to determine variation patterns in important characteristics, and two others extend to establishment of seed orchards. (46) The variation represented in the Caribbean pine-slash pine complex, highly important to forestry in the South and elsewhere in the world, is being studied by North Carolina State University. Cones, seeds, needles, wood and oleoresins have been collected from 380 trees--the most complete collection ever made--in the Bahamas and Caicos Islands. The wood analysis of specific gravity and fiber morphology, which nears completion, provides information that will be of special interest to pulp and paper manufacturers in the South, and for selection of tree material to introduce into other countries.

(47) A somewhat similar study of variation is underway in Oklahoma with shortleaf pine. Here, the researchers are interested in identifying the geographic gradients of variation in important properties within the state. When these are known, the best zones for seed collection can be established.

(48) Clemson University has evaluated 50 select loblolly pine trees, of which 35 will be represented in seed orchards. Sixteen sources of redcedar are being grown in the nursery.

(49) At Auburn University, seed orchards of loblolly, slash, longleaf and Virginia pine are being established in cooperation with the Alabama Division of Forestry as a major step in developing improved varieties. Land areas have been prepared for three five-acre orchards and one 100-acre orchard and 57, outstandingly good trees are being grafted onto rootstocks.

(50) Development of a selection scheme and selection of superior phenotypes of yellow-poplar are the first steps in a new project at West Virginia University for supplying high quality seed sources of this species. After two summers of intensive search by two workers, 32 trees of very high vigor and excellent form have been found. Some of these, plus others yet to be located, will be incorporated into orchards for seed production.

(51) West Virginia University is also beginning intensive studies to produce black cherry seeds of high genetic quality. This high value cabinet wood will by all signs continue to be much in demand in the future. Samples of the wood of promising trees are being removed with the powered coring device shown in Figure 12. The core is one inch in



Fig. 12 - Sample wood core for determining wood properties, and the power-driven portable coring device used to remove it from the tree. The power source is the "Little Beaver" girdling tool. Information from cores will be used in the West Virginia University hardwood tree improvement project MS-1.

diameter and may be up to 12 inches long. The cores are studied to determine specific gravity and other wood quality indicators of major interest. Specific gravity in this species varies strongly, and may be fairly closely determined by heredity.

(52) Selection of the best available seed sources of sugar maple for high-quality growth in the Lake Superior region is the aim of research at Michigan Technological University. Seedlings have been collected from 15 eastern states and planted in the Keweenaw Peninsula of Upper Michigan. Trees from these seed will be compared annually with select specimens exhibiting rapid growth or other desirable characteristics. Wood samples from the eastern United States and Canadian seed source locations are being tested for wood quality.

(53) At Oregon State University, researchers are concerned not only with finding trees that grow faster but also with why they grow faster. This is the question being studied, using seed from controlled hybridization between contrasting races of trees.

(54) At Washington State University, a survey is being made to learn more about the tendency of lodgepole pine to produce several bursts of growth (multinodality) in a single season, and about the extent to which the number of such bursts (nodes) is conditioned by environment, and heredity. Evidently the number of nodes does not vary clinally (gradual change along some gradient), as suggested by some earlier observations. Binodality is the most common expression of node number. Uni-nodality is more frequent in coastal and high altitude stands than at middle elevations (5,000 ft. or higher). Four nodes in one year is the maximum number expressed in stands investigated, and is most likely to be found at middle elevations from 2,500 to 3,000 feet in northeastern Washington, northern Idaho, and northwestern Montana. Frequency of quadrinodality rarely exceeds 2-4 percent in these locations; however, trinodality may occur as frequently as 25 to 30 percent and is found at all locations to some extent, although least frequently along the coast and at high elevations. For use in studies to determine the importance of inheritance as a cause, seeds have been collected and sown and controlled pollinations made.

Attempts to root fascicular buds of lodgepole pine taken from 6-to-8-year-old stocks have met with sufficient success to encourage further study. About 1 percent of fascicles treated grew roots, but no buds emerged from these cuttings.

BREEDING

Development of improved varieties of forest trees by breeding is now active in many states. As in genetic improvement of other organisms, the heritability, or degree of genetic control, of economically important characteristics must be determined. Hybridization, including sometimes its difficulties, and studies of self-fertilization behavior are also important features of some of the research programs.

(55) At the University of Idaho, the heritability of stem, crown and branching characteristics of ponderosa pine is being determined from a series of crosses made between different types in 1964. Initially, cone and seed characteristics resemble those of the seed tree. In addition, a survey is underway of the range and pattern of genetic variation in ponderosa pine. Begun last year at the species' northern fringe, in British Columbia, and adjacent states, the survey extended this year to Oregon, Montana, Wyoming, and the borders of Colorado and the Dakotas.

(56) The University of Georgia has just completed a study of much value for seed orchard development. The results show how strongly certain external traits are inherited in slash pine.

(57) Heritability is also involved in a study of Oregon State University to determine whether differences in developmental rate of Douglas-fir embryos are the result of environmental or genetic controls. High elevation seed of Douglas-fir consistently has relatively high germination. To learn why, periodic collections of developing embryos were made at both high and low elevations, and reciprocal grafting of branch wood has been started, using trees with consistent histories of high seed production. There appear to be differences in frequency and pattern of cell division related to environmental difference. High elevation seed is more subject to damage at the time of collection and to greater loss of viability.

(58) At the University of Missouri, some interesting studies have been made to determine the effects of environmental conditions at the time of pollination, within bags, in pine species. Conclusions reached so far are as follows: (a) A good supply of soil moisture during the brief pollination period is highly essential to cone set and normal seed development. Irrigation of seed trees during the critical period of pollen flight, if needed to assure a liberal supply of water, can be highly beneficial. (b) Constantly warm temperatures and constantly high atmospheric moisture contribute to poor cone set and to low seed yields in those cones that do mature. (c) Given a good supply of

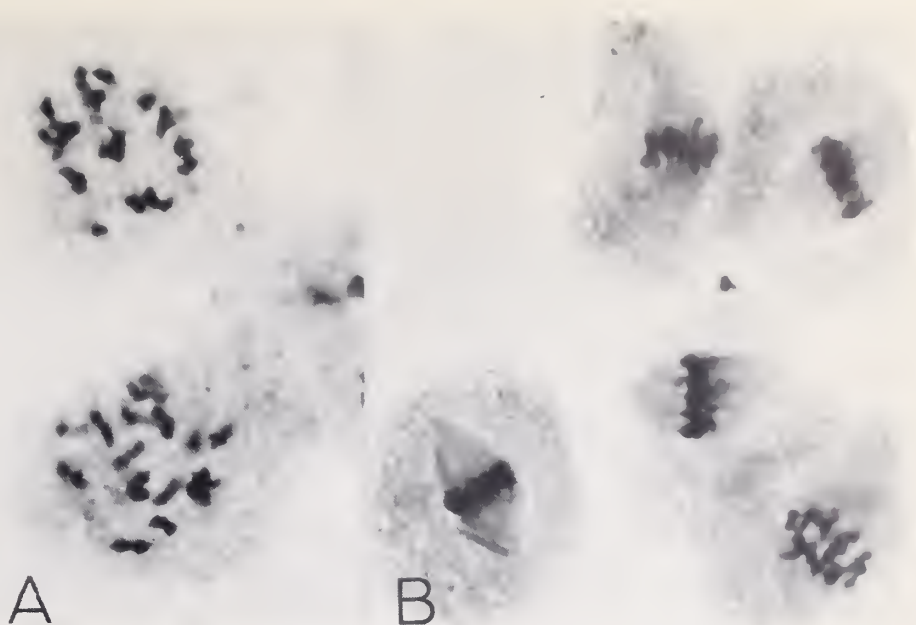
soil moisture during the pollination period, the most favorable atmospheric regime for optimum functioning of the pollinating process seems to be one of dry days with moderate temperatures, accompanied by cool, moist nights.

These results appear meaningful from several standpoints. They provide an explanation as to why pine species are reproductively competitive in various climatic zones and on certain soil areas, while failing in other locations. Similarly, some insight may be realized in efforts to understand the occasional nature of good pine seed crops in nature. Also, the particular pollination dates of pine species under certain prevailing climatic circumstances, such as the winter pollination of pines on the Florida peninsula, may be seen to have adaptive advantage. Through an analysis of these findings, an hypothesis for the physiology of the pollination mechanism in pines has been derived.

(59) Another study of the reproductive influence of environment is being carried out at Oregon State University. In this case, the investigator is interested in effect on the induction of early flowering in previously non-flowering Douglas-fir trees. The normal ten to fourteen years now experienced is a roadblock toward rapid advancement in the tree improvement program. One approach now being tried is to discover if modification in the physical environment--cooler summers, warmer winters, etc.--might induce early flowering in young Douglas-fir. The first replications of a five to ten-year study were subjected to a cooler July last summer and some of the practical problems of environmental control have been solved.

(60) Crossing and inbreeding are being investigated in a project at the College of Forestry at Syracuse University which is aimed at specific aspects of potential genetic improvement of some high-value hardwoods. The sequence of events in sexual reproduction is being studied in black cherry, including counts of the chromosomes and development of the embryo. See Figure 13. Early attempts at inbreeding show a strong self-incompatibility reaction and cross pollinations have been difficult to make. Results from crossing yellow-poplar from Mississippi and New York, however, have been more encouraging. Early hybrid growth rate is superior to the New York trees and much has been learned about methods of breeding and pollen storage, and possible reasons for seed inviability in nature.

Fig. 13 - The chromosomes of black cherry, magnified 2,000 times. Chromosome groups in A and B are in different stages of division, leading to the formation of the heredity-carrying pollen grains, each transmitting a set of 16 chromosomes. College of Forestry at Syracuse University project F.



(61) Self-pollination behavior and effects are being studied in Virginia pine at Clemson University with the possibility in mind that purellines may be established for hybrid production, much as in corn. Wide differences in seed set were noticed among the first 25 trees on which self-pollination was attempted. The number of apparently sound seed varied between zero per cone for 6 lots to as high as 18 per cone for 2 lots. The average number of sound seed per cone was 3.51 compared with 7.04 for the check lots. In general, the better producing trees were high in seed set for both check and self-pollinated lots.

(62) The Ohio Agricultural Research and Development Center hopes ultimately to develop new white pine hybrids resistant to certain diseases and insects. Some reproductive incompatibility between white pines is a problem now being investigated.

(63) Reproductive compatibility between the blue and Engelmann spruces, both naturally pollinated and control pollinated to induce selfing or produce species crosses, is under study at Colorado State University. Little difference in numbers of seed per cone, which averaged 200 seed per cone, were obtained from 59 artificial crosses made in 1964. Germination tests will be made of the seed from these crosses and also from the 139 crosses made in 1965. Blue spruce pollen remained viable for as long as 11 years, nearly 30 percent in culture media at 50 percent relative humidity and 0 and 4 degrees C. Germination was greatest in the 15 percent sucrose medium after 11 years storage; for fresh pollen, it was greatest in 10 percent medium. Systematic records of foliar and floral development were kept of the two spruces at seven

altitudinal stations. Preliminary review of records suggests that pubescence may be related to altitude and would therefore be questionable as a character to identify and distinguish the two species, which are similar.

Three additional researches in Minnesota, Wisconsin and Montana feature hybridization.

(64) At the University of Minnesota, 150 controlled crosses were attempted involving various combinations of quaking aspen, bigtooth aspen and European aspen. The crosses were made on cut branches forced in the greenhouse. Seeds were produced in sufficient numbers in about 40 percent of the crosses. All seedling propagation was carried on under greenhouse conditions but was in general unsatisfactory due to mortality from damping-off and other causes. Treatments with Captan indicated that this fungicide can effectively control damping-off. The new greenhouse facilities now under construction will aid the aspen propagation program. Direct seeding in nursery beds at the Cloquet Forest Research Center is also planned. A replicated out-planting of 69 clones of a western black cottonwood family, including the original parents, 11 of their first generation progeny and 56 members of the second generation (F_2), was made in the spring of 1965. The difference in time of growth cessation of the parents is about three weeks. The first generation hybrids stopped growth at an intermediate short interval of time, whereas the time of growth cessation of the second (segregating) generation appears to range throughout the three-week span separating the onset of dormancy of the original parents.

(65) To develop methods for producing hybrids between red pine and other pine species, principally European black pine, is the goal of a project at the University of Wisconsin. It is hoped that successful hybridization may contribute important new variation for use in selection and breeding genetically improved forest planting stock. Controlled pollinations have been made during the past two years to test four approaches to producing hybrids between red pine and European black pine, as follows. (a) Several different pollen mixes, each representing 5 different trees, were used in pollinations between species. These mixes represent a potential shortcut in screening for compatible genotypes. Any pollen mixture that fails to produce seed on any of several maternal parents is unlikely to be of value in hybridization between the species. Any pollen mix that does produce seed can be separated into the component trees and tree-to-tree compatibilities can be worked out in further crosses. (b) Mixes of pollen from both species were used to test the idea that the presence of pollen from the maternal species may maintain the female cone adequately for some interspecific fertilization and seed development. Seed has been extracted from red pine cones and is being extracted from black pine cones. The results with red pine show little promise of hybrid seed from direct crosses

between species. Quantities of filled seed varying from a few to several hundred are available from crosses with interspecific pollen mixes. All seeds will be sown in 1966 for evaluation of progenies.

(c) For crosses between species, pollen was given low doses of gamma irradiation in an attempt to stimulate pollen germination and growth, thereby increasing the chances of fertilization and seed development.

(d) For crosses with interspecific pollen mixes, pollen from the maternal species was given a high dose of irradiation to destroy the genetic capability. This pollen was then used in mixtures to test the idea that physiological benefits of pollen could be obtained from interspecific pollen mixtures. Cones from these 1965 crosses will be harvested in October and November 1966.

(66) At the University of Montana it was discovered that hybrids have been formed in nature between western and subalpine larch on a mountain-side where the two species occur together. Diagnostic characteristics have been determined by which hybrids may be recognized. Such hybridization expands opportunity to select for desirable characteristics in tree breeding. The genetic variation within each of the two species is also being investigated.

(67) The University of Washington is studying the effects of a single gene on the morphogenesis of a model plant, the tomato. The results will be helpful later with homozygous western black cottonwood. The results from the first step in a backcrossing program show that the expression of the lanceolate gene depends on the genetic background. In the process of transferring the lanceolate gene to a new, desirable, genetic background (high number of flowers per inflorescence), a significant increase of the flower number has been recorded in the lanceolate plants of the F_1 generation. This means that a shift has occurred in the expression range of the lanceolate gene, and a further desirable shift may be accomplished from additional backcrossing.

SILVICULTURE

Silviculture deals with theory and practice of establishing, tending, and growing the forest. Our traditionally large silvicultural research effort has recruited only a sprinkling of McIntire-Stennis projects. Active research reported from a dozen states represents the subjects of seed, forest reproduction, stand treatment, special tree products, and special-purpose plantings.

SEED, REGENERATION

Successful survival, establishment, and growth is the common objective of research on planting or seeding. Forest regeneration measures formerly avoided as infeasible may now justify research. Factors contributing to this change include: enhanced value of land or timber, more efficient cultural practices, improved biological knowledge, and last but not least a better recognition of the potentials of research.

(68) At Clemson, an industrial X-ray unit and film show promise for evaluating seed quality of major timber species. X-rays of the embryo plant inside the seed varied in effectiveness by tree species from excellent on slash pine and ash to failure on sweetgum. The X-rays have given good prediction of viability of the seed of loblolly pine and yellow-poplar--but X-raying must be done before the moist stratification of the seed.

(69) At Nevada study deals with establishing Jeffrey pine on dry east slopes of the Sierra Nevada. Test seedlings of this large-coned cousin of ponderosa pine were a total loss to mice. Spring-planted seedlings showed a good average survival of 65 percent through the first summer that enjoyed double the normal rainfall. Follow-up tests will continue.

(70) A Tennessee study evaluates the relative 24-year-growth of pure and mixed plantings of yellow-poplar, eastern white pine, and short-leaf pine.

Determining the best treatments for effective establishment of high-value hardwoods is the subject of research in southern Illinois.

(71) and Indiana (72). Both studies show striking first-season benefit to planted hardwoods from increased moisture. Keeping down competing weeds was the key--either by cultivation, or preferably chemical weed treatment. This is a bare beginning of research on a number of projects that will test varied cultural treatments on high-value tree species.

TIMBER STAND IMPROVEMENT, THINNING

(73) Cuttings, other than harvest, for improvement of the stand have come into use in intensive management by American foresters. Accordingly these treatments are less prominent in new research projects than in older and many continuing studies. One Georgia project was initiated as a follow-up in a 100-acre tract that had been placed under management eight years earlier. Useful results of earlier research are being salvaged here.

SPECIALTY TREE PRODUCTS

The special tree or secondary forest products represented are Christmas trees and essential oils. Christmas-tree production has matured to an intensive culture that may be combined with other forest land management or concentrated on independently.

(74) The Kansas project deals with the relative adaptability and management of a number of conifers for Christmas-tree production. Thus a favorable shearing date for white pine should precede and Virginia pine may follow the date for Scotch and Austrian pine. This permits distribution of the work load.

Balsam fir projects in both New Hampshire (75) and Vermont (76) should yield useful cultural guides. Thus basal pruning of lower branches reduces leader growth and stimulates bud development between whorls. Spring clipping and shearing and fall clipping increase the count of lateral branch tips in young trees. Injuries by frost or fertilizer excess can be serious. Transplanted wildling balsam fir looks good after two years.

(77) A study in Utah deals with essential oils or distinctively scented aromatics from five important native conifers: pinyon, and single-leaf pinyon, Rocky Mountain, Utah, and one-seed junipers. An experimental still has provided a series of essential oils for complete chemical assay, after their favorable appraisal by major industrial concerns. Analyses will cover both sapwood and heartwood, as well as oils of each of the pines and junipers for different seasonal collections.

SPECIAL PLANTINGS

Windbreaks and shelterbelts are the subject of projects in four prairie states. (78) The Kansas project provides analyses of failures on established windbreaks.

(79) A Nebraska project has concentrated on developing instrumented facilities to evaluate effects of windbreaks. A trailer laboratory is equipped for meteorologic recordings, such as wind velocity and direction, soil and air temperature, atmospheric moisture, solar and net radiation, and soil thermal flux. The system permits automatic scanning of 40 voltage-producing sensors, 10 counting instruments, and data storage on punched paper tape for direct computer analysis. A supplementary infrared gas analyzer accommodates successive samples, as for carbon dioxide concentration, signaling automatic records on punched tape. This equipment permits micro-meteorological observations at several critical points with reference to windbreaks.

(80) The North Dakota project has dealt with a survey of varied conditions observed in shelterbelts. The understory cover in multiple-row shelterbelts showed increased grass percentage with increasing years since the belt was last cultivated. Thus, 1 to 5 years after cultivation, the grass averaged 13 percent, weeds 87 percent; whereas, 15 years or more after cultivation, the grass was 70 percent, weeds 30 percent. Tree seedlings, chiefly 1 to 5 year-old elm and boxelder, abounded in the 10-to-15-year-old shelterbelts. In old belts opened up by decadence of trees, mostly cottonwoods, the grass and weed cover was too dense to permit tree reproduction. The yield of understory vegetation is depressed by the competition of overstory trees. Thus under shelterbelts of all ages, clippings averaged 100 pounds per acre, dry weight: whereas clippings of similar plant material growing in open fields would be over 3000 pounds per acre. In a 2-year-old field nursery, ponderosa pine, of varied sources and inoculation with forest soil, showed mycorrhizae on all old roots of surviving seedlings. Treatments underway include acidifying the alkaline Fargo clay loam with sulfur, and testing various chemicals for control of weeds in Siberian elm rows. In shelterbelts examined, defoliation by the fall cankerworm appeared worse than other insect damage. Apparently insects did not limit tree survival directly, but could depress the growth rate of certain tree species.

(81) A South Dakota project is directed toward finding factors that limit the success of tree plantings on prairie sites and developing cultural practices that will favor success of such plantings. In this area of widely needed advances in knowledge, research findings would have immediate use in afforestation of recreational sites along the reservoirs of the Missouri River. Moisture deficiency is a recognized major cause of failure of trees on grassland sites. Hence, practices that increase the store of moisture in the soil or reduce the loss of available moisture should improve the chance of survival and encourage more rapid height growth of trees. With cooperation of the U. S. Corps of Engineers, research plots with pre-planting and post-planting studies were established this spring in the vicinity of dams at Big Bend and Oahe. Chemical fallow treatments were applied in three-foot contoured strips on slopes covered with native grasses. Here the killing of the live sod is a form of site preparation for

tree planting adapted to land too steep for conventional cultivation. Treatment achieved almost 100 percent kill of native grasses and annual weeds, from combination application of simazine and dalapon. Dalapon was applied at two different times to control both cool and warm season grasses. By the end of the growing season, soil moisture content in the top three feet was about 30 percent higher in the treated plots. Irrigation and fertilization trials were initiated in 1965-planted conventional shelterbelts along the shoreline of the Big Bend reservoir. Height growth of green ash and Siberian elm showed good response on the treated plots; the combination of irrigation and fertilization treatments was more effective than either one alone. Chemical weed-control trials applied over 1965-furrow-planted ponderosa pine gave significantly higher survival than in untreated plots. Treatments with simazine, amazine, and dalapon controlled all annual weed growth, and depressed native grasses and perennial forbs with no injury apparent on the pine.

FOREST PROTECTION

Forest protection research on fire, pathology, and entomology is of utmost importance to forest and wildland management. Current trends show increased intensity of management of forest land and emphasis on optimum use of natural resources. We have sharpened awareness of needs for forest protection and recognition of enhanced values. Accordingly, research on forest protection can be more readily justified. Productive research in each of the three areas--fire, pathology, and entomology--calls for scientists of extremely advanced scientific knowledge and skills. Availability of advanced scientific equipment and powerful techniques will permit these scientists to make significant research contributions in forest protection. Needed expansion in graduate training and research in fields of forest protection seems well adapted to the McIntire-Stennis program.

FIRE

Research on fire by forestry schools and state experiment stations appears too limited, whether relating to control of wildfire or prescribed burning to reduce hazard.

Among McIntire-Stennis projects, one at Cornell on vegetation after burning in hardwoods (45) was grouped in Ecology; a project at California (82) soon to be activated relates to vegetation and fuel hazard manipulation in wildland management.

(83) A project in Montana deals with describing the regeneration of conifers after prescribed burning of logging slash. Observations now being analyzed show that conifer seedlings vary widely with site, fire behavior, and source of seed.

(84) A project at Louisiana Tech measures differences between an annually-burned plot and an unburned plot of longleaf pine. A difference was found in steam-distilled oleoresins: trees in burned plots may produce resin that contains a non-volatile isomer that interferes with ultraviolet determination of abietic acid.

PATHOLOGY

(85) A study on the globally destructive fungus associated with littleleaf, Phytophthora cinnamomi, in Hawaiian forest soil focuses on how altitude and temperature affect its survival and growth. The

atmospheric pressure that occurs at 20,000 feet does not adversely affect the growth of Phytophthora cinnamomi. The fungus is sensitive to both high and low temperatures. It is killed by freezing (-20°C in the experiment) and cannot be recovered from infested soil after 2 weeks at 37°C (or 109°F). This sensitivity of the fungus to heat may allow heat therapy of some types of infested plants.

(86) The objective of this study at Washington State University is to determine the life history of the important wood-rotting fungus, Hypoxylon fuscum. This fungus has been induced to complete its spore-to-spore life cycle on alder wood in a constant-temperature growth chamber. Cytological and anatomical studies are being conducted on the relationship of H. fuscum to other Hypoxylon species and conditions under which alder wood is destroyed. This study leads to better understanding of the cause and ultimately perhaps the control of wood decay and forest tree disease.

(87) The world-wide fungus Fomes annosus is studied as the root- and butt-rot of shortleaf pine in Missouri. Fomes annosus infections in pine plantations result from the invasion of stump surfaces exposed in thinning operations. The application of chemical protectants to freshly exposed stumps is currently recommended for the control of this disease. Investigations deal with seasonal fluctuations in the amount of airborne inoculum of the fungus; the incidence of infection in freshly cut stumps; and the relations of time of cutting and application to the efficacy of certain stump treatments. Monthly exposures of pine discs, used as spore traps, and collections of foliage for spore washings showed that Fomes annosus airborne inoculum was highest in winter and lowest in summer. The rate of spore deposition in winter was 10 to 30 times greater than in the summer. In winter, 90 to 100 percent of the freshly cut pine stumps became infected, in contrast to 0 to 30 percent infection during the summer. These results indicate that fewer infections will occur if plantation thinnings are made during the summer months. There was no change in the receptivity of stumps to infection over a three-day period. Urea and borateem were 100 and 95 percent effective, respectively, in preventing stump infection if applied within an hour after cutting. Delays of 24, 48, and 72 hours in application, however, markedly reduced their effectiveness. The application of these protectants to exposed stump surfaces should, therefore, be made as soon as possible after cutting.

(88) The Minnesota project on ecology of wood decay has concentrated on the role of insects in disseminating wood-rotting fungi. Certain sapwood-rotting fungi were collected from free living insects, including the mosquito. From wounds on roots of jack pine, Ceratocystis serpens, a stain fungus was isolated and two wood rotters, Armillaria mellea and Polyporus abietinus, were recovered. In young aspen, 53 percent of the trees had insect wounds which could account for the discoloration in these trees.

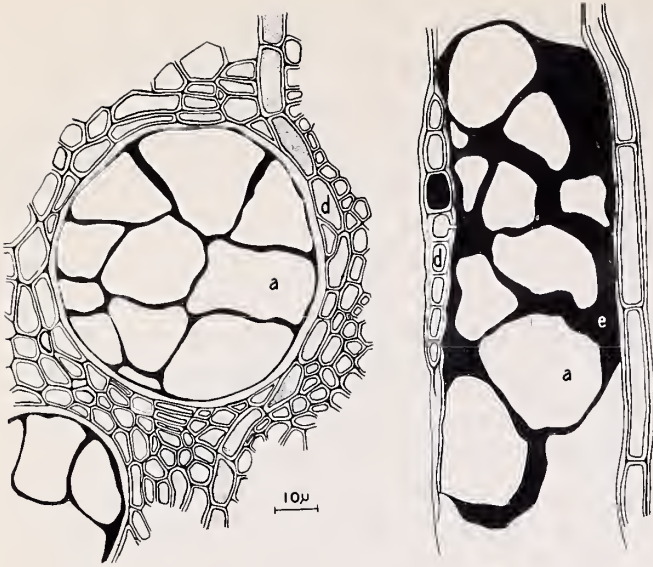


Fig. 14A - Spores of the oak wilt fungus inside a water-conducting vessel.



Fig. 14B - A residential area in which oak trees have been killed by the oak wilt disease.

(89) Research on oak wilt, its development, spread, and control at Wisconsin concentrates on unique microscopic and chemical techniques, basic distinctions between the highly susceptible red oaks and resistant white oaks, and mechanisms for oak wilt resistance. Oak wilt, incited by the virulent fungus Ceratocystis fagacearum, is a serious wilt disease of oaks and several related species. Oak wilt has spread alarmingly among both shade and forest trees in eastern and central United States, and constitutes a potential threat to oaks throughout the world. The causal fungus is spread over long distances by certain insects, and from tree to tree through root grafts or fresh wounds in the spring. Infected red oaks wilt, defoliate, and die rapidly when the water-conducting vessels become plugged with gums and balloon-like growths. In contrast, white oaks often escape infection, or if infected, survive for years since fungus invasion and plugging are limited. Unfortunately, infected white oaks may provide a continuous source of infection since the fungus may fruit year after year. The fungus also persists in infected roots and may reinfect above-ground parts in subsequent years. In the spring, fresh wounds remain susceptible longer during wet, cool weather, than during hot, dry weather. In infected red oaks, foliage wilt develops as water movement and trunk growth stop. Infected white oaks, however, continue to grow and new wood "buries" the fungus. Grafted roots are "adopted" by adjacent healthy trees. Avoiding or treating wounds has reduced long-distance spread by insects. Severing grafted roots, mechanically or chemically, has prevented tree-to-tree spread. Soil fumigants are effective. Chemical injections of antibiotics or growth regulators have provided promising protection. Disease resistance is sought in oak seedlings collected from northern United States. Results have clarified other vascular wilt diseases of trees and control measures have been adapted for the Dutch elm disease.

(90) The project on etiology of maple decline in Massachusetts seeks to define this serious disorder and causes. Decline is more serious in soils where depths are shallow, and water and nutrient-supplying ability limited. Nematodes--ring, sheath and dagger--have been found in greater abundance around roots of declining maples than around comparable healthy trees. Scorch of leaf margins and die-back of twigs and branches in sugar maples along roads treated in winter with rock salt (sodium chloride) related closely to the amount of chloride in the leaf tissue, but not to the amount of sodium. If the chloride reaches one percent of the dry weight of the leaf, severe injury results. The normal level of chloride in sugar maple leaves is about one-twentieth of one percent. No evidence of primary insect involvement above ground was found at the 17 sites in western Massachusetts--not along roads--on which maple tree growers reported decline. So far, attempts to transmit virus symptoms from declining maple trees to healthy maple and other plants have been without success. Many fungi and bacteria have been isolated in pure culture from woody tissues of 77 unthrifty maple trees that were closely examined. They include such usual disease organisms as Verticillium, Cytospora, and Nectria, some organisms not usually associated with tree diseases, such as Illosporium and Pullularia, and several bacteria.

(91) The Maryland project on forest tree seedlings and soil fungi relationships concentrates on the age at which pine seedlings become resistant to damping-off by Pythium spp. Virginia pine seedlings at 10, 15, 30, or 50 days after emergence were inoculated with Pythium debaryanum by using three techniques and outcomes as follows:

(1) pouring mycelium over the soil gave maximum damping-off in 15-30 day old plants; (2) inserting mycelium into wound in the base of each hypocotyl, killed all plants; and (3) placing the washed roots on PDA cultures of the pathogen. Here the destruction of host tissue decreased with increased age at treatment to a negligible level of damage at 50 days. Parenchyma tissues of all plants, including those resistant to damping-off, were colonized by the pathogen. A suberized endodermis which could be first detected in 30-day old seedlings, however, appeared to restrict advance of the pathogen, and, parenchyma cells inside the endodermis contained only about 1/3 as much mycelium as those outside. The suberized endodermis in roots of 50 day-old seedlings was well developed and surrounded approximately 90 percent of the sparsely colonized parenchyma.

(92) Research continues on the cause and control of oak decline in Texas. The causal agent has been identified as Cephalosporium sp. This fungus has been isolated from naturally-infected live oak, water oak, southern red oak, and post oak. The oak decline disease has been experimentally reproduced with the fungus isolate in potted and nursery-maintained oaks.

(93) The objective of a continuing project is to survey and study the incidence, distribution, and etiology of important forest tree diseases in Puerto Rico. Initially, attention has been given to decline of West Indies mahogany (Swietenia mahagoni). Mahogany decline shows low incidence and severity in the Guajataca forest in the northwest of the island. However, in the Susua forest, in the southwest of the island, a large proportion of the trees are affected and dying. Several fungi were isolated from the bark and wood of such trees. Phytoparasitic nematodes of the genera Xiphinema, Hemicyclophora and Rotylenchulus were found in the rhizosphere soil of these trees. Another important tree disease is stem canker of eucalyptus which damages valuable trees. During the spring months, large cankers with black exudate were commonplace. By October most of the cankers had disappeared. The healed areas were gall-like in appearance. Internal tissues of these galls were stratified; layers of wood alternated with hardened masses of exudate. A dark moniliaceous fungus, not yet identified, was consistently isolated in pure culture from affected tissues as well as from the exudate.

(94) A Pennsylvania project on an annual canker of maple, concentrates on conditions of environment and tree that favor wounds that provide entrance for the fungus, Fusarium solani, and requirements for successful colonization by the fungus. Repeated measurements of soil temperature and moisture at many locations within a maple stand confirm indications that roots of cankered trees occupy less favorable sites within the stand. This suggests that certain trees are predisposed to injuries leading to successful attack by the fungus. Inoculation tests with Fusarium solani show that the spores can germinate on bark and wood tissues, but the fungus mycelium grows only on cambium and xylem tissue, indicating the requirement for deep wounds. Isolation tests made from the healthy bark of both cankered and uncankered maples show that Fusarium solani, and many other species of fungi, were commonly present.

ENTOMOLOGY

(95) Investigators at the Arkansas Agricultural Experiment Station were successful in introducing disease organisms into sawfly larval populations in small scale tests. The period of incubation was 4-5 days. A technique to force eggs to hatch in the laboratory either before or following normal hatching period was developed. Studies also revealed the pupal stage may persist under field conditions for three seasons.

(96) At Kansas State University the Nantucket Pine Tip Moth can be damaging to shortleaf pine, Virginia pine, pitch pine, jack pine, Scotch pine, and ponderosa pine. Light trap collections indicate that there are three generations of the tip moth in Kansas each year. The cedar webworm was found seriously injuring eastern redcedar in wind breaks and shelter breaks in central Kansas. See Fig. 15.



Fig. 15 - Webbing injury from southwestern budworm on eastern redcedar.

(97) Researchers at the University of Maine have found that a forest which is susceptible to pine leaf aphid damage contains a high proportion of host trees to aphids, is a mixed stand of pine and spruce, contains a large spruce component, and includes sites with relatively poor growth of pine.

(98) Work at the University of Montana has shown that Douglas-fir defoliation caused by spruce budworm increases with tree height, crown closure, and with the increased percentage of Douglas-fir in the forest mixture.

(99) Studies at the University of Wisconsin have shown that 15 species of coniferous sawflies occur in the state. Fundamental information has been accumulated for use in predicting sawfly population trends. Biology and seasonal history studies have been made of Neodiprion rugifrons, a common pine sawfly in Wisconsin.

(100) Research at the Vermont Agricultural Experiment Station deals with the white pine weevil's cumulative set-back to the height of dominant white pine trees. Weeviling of the terminals of the tallest trees tends to impair estimation of site quality by height on age of tree.

(101) Trunk implantation of methyl demeton, 1 gram per diameter-inch, in Douglas-fir, by researchers at the University of Idaho, failed to produce consistent reductions in seed loss due to insect attack. These results are in contrast to those obtained in 1964 when injections per tree supplying up to 3 grams per diameter inch were used.

(102) Examination of cone collections by scientists at the University of Maryland during the period April to September revealed two additional species of pine coneworms. Information on life history cycles of cone-worm species was obtained from these studies.

(103) Workers at the New Mexico Agricultural Experiment Station have found that major damaging insect species to seeds and cones of ponderosa pine are the ponderosa pine cone beetle, the pine coneworm, the pine seed chalcid, pine seed moth, and a midge. The ponderosa pine beetle alone may damage 99 percent of the seed. With Douglas-fir, the fir coneworm, the fir seed moth and a midge were the principal seed and cone insect pests. Seasonal life history studies and the use of systemic insecticides as a means of control are receiving attention. See Fig. 16.



Fig. 16 - A portable extension ladder is necessary for conducting biological studies on seed and cone insects.

(104) At the Puerto Rico Agricultural Experiment Station attempts to find parasites of the cedar shoot borer have been negative. Consideration is being given to importation of parasites. Disyston and endrin are being evaluated for control of this pest.

(105) Field observations indicate that Nasutitermes costalis, an arboreal termite, is a prevalent species in the humid areas of Puerto Rico. Collections list more than 120 host trees for this termite. Another termite species was found, Nasutitermes nigriceps, well adapted to dry conditions; and in humid areas it occurs only at lower elevations. So far, 60 host trees have been recorded for this species.

(106) Researchers at the University of Michigan have demonstrated the capability of interbreeding among the 3 species Agrilus anxius, A. liragus and A. horni. On these closely related species infesting aspen and birch, other behavioral habits are under continued study. Some observations indicate a tendency for species isolation.

(107) Efforts at the Texas A&M University to develop artificial diets for the southern pine beetle have met with some success. Adult insects are being tested for preference to volatiles and extracts. Reaction to these tests can give leads for diet ingredients. Success in developing a diet should facilitate rearing these pests in the laboratory for accelerated research study.

(108) It has been determined at the University of Washington that motor responses of the Douglas-fir beetle are influenced by parasitism and genetic variation of a beetle population. Visual response is quite high, light direction being more important than light intensity.

(109) Studies at Michigan State University indicate that forest stands treated with persistent insecticides have as many predatory spiders, ground beetles, ants, millipedes and centipedes as untreated stands. Partial analyses of collections show at least 23 genera and sub-genera of predaceous ground beetles and 28 species of spiders native to Scotch pine plantations.

(110) The University of New Hampshire is making a qualitative and quantitative study of springtails and mites that are important in the reduction of dead plant material, primarily needles, in the forest floor of the white pine type. Over a hundred species have been collected. Their density has varied from 21 to 250 individuals per cubic inch of soil. Their numbers have always amounted to more than 90 percent of all the organisms extracted from soil samples.

FOREST MANAGEMENT

Here, forest management has the scope defined in the McIntire-Stennis Act. The broad spectrum of research includes in addition to management of timber such multiple-uses as recreation for human enjoyment, wildlife and fish, range for forage, and watersheds for yield of water. The acceleration of intensive forestry appears reflected in increased numbers of foresters. On a little-changed forest land acreage foresters will be able to concentrate more effectively. Their function will increasingly have a multiple use orientation and their work must be supported by research backing up both the several and the integrated uses of forest lands. The unfolding McIntire-Stennis forestry research emphasis appears realistic in these circumstances of management.

TIMBER MANAGEMENT

(111) In New Mexico costs and returns of present forest management practices are being determined from a survey made of forest owners. At current prices reforestation is not an economical practice. Returns from timber stands under typical New Mexico site conditions average \$60 per acre in a rotation period of 120 years. The cost of leaving seed trees, \$5 per acre, carried at a low rate of interest will exceed this amount in 120 years. A landowner would need an incentive payment of \$3.35 per acre to break even on the practice of leaving seed trees over the rotation period. Seeding or planting costs far more per acre, and thinning and pruning forest stands appear to be economically marginal operations. Apparently, New Mexico forest landowners do not make enough from selling wood products to invest in forest management practices.

(112) In a University of California project, computer-oriented mathematical models appear to hold promise as tools for solving complex timber production scheduling problems. Advantages of the models compared to the classical allowable cut formulas are: (1) their ability to combine a complex set of forest conditions and management objectives; (2) the ease of studying the effect of alternative harvesting policies of timber output.

(113) A project at Purdue aims to develop a linear-programming model for combined planning of farm and woodlot activities to permit testing whether, under particular economic and growth conditions, investment of farm labor and money in woodland activities is justified. Two significant results have developed from this project up to the present time. The first is the demonstration that woodland activities stay in the optimum plan, even when the profitability of the most efficient recent methods of farm management is incorporated. The second significant result is the development of a step-wise planning model that permits

the long-term consequences of present activities to exert their influence objectively in the planning process. It has been very encouraging to find woodland activities included in the optimum farm plan. Two reasons for this become apparent when the model is studied carefully. (1) Woods work is flexible as to time of year and can be a means of turning hours of slack labor into capital of standing timber, or, immediate income of logs marketed. (2) It is now possible to show considerable increases in growth value on timber in the central hardwoods region when timber stand improvement activities, such as cull-tree poisoning and pulpwood-marketing of low-quality trees can redirect the growth potential of the site to higher quality and more rapidly growing trees. Timber stand improvement work was included in the optimum farm management plan.

(114) In a Michigan State University project net returns from forest management for wood production will be determined for planted red pine and natural stands of southern Michigan hardwoods with varying cultural practices applied to them. Results from computer processing will identify the most profitable forest management opportunities and provide a sound financial base for planning forest management programs.

MENSURATION

(115) In one Oklahoma project to evaluate timber conditions in the Ouachita Highlands, examination of continuous forest inventory plots revealed forest site contrasts associated with geologic formations.

(116) Another Oklahoma project deals with patterns of tree distribution found in major types of the United States. Varying degrees of clumpiness and contagion characterize all tested tree populations. In general, hardwood associations showed the least amount and intolerant pine types the greatest amount of both contagion and clumping. Southwestern ponderosa pine shows the most consistent pattern of clump-wise arrangement. Possibly, age-class groupings are associated with moisture tension zones, and infrequent successful seed years.

(117) A Georgia project to compare efficiency of fixed-radius sample plots and point-sampling for two forest stands is completed. Comparisons of timber cruising methods indicate that in bottomland hardwoods 1/10-acre plots and point-sampling give the greatest precision in the least time. For pine cruising, 1/20- and 1/10-acre plots are most efficient.

(118) In an Arizona State College project to compare measures of stand density for ponderosa pine in the southwest, 121 plots have been established to represent young ponderosa pine of varied density.

(119) One Purdue project aims at predicting timber yield in uneven-aged stands of mixed species. Progress has been made in developing equations for trends in mortality from records on plots that have variable mortality, also for estimating future growth on survivor trees. The remaining steps are to find similar equations for ingrowth of young trees and, most important, the way to combine these in a computer program.

(120) The objective of one Purdue project is to develop mathematical models of the growth of even-aged forest stands from seed germination to final harvest. These models will reflect the natural variability in biological processes that may be expected. Some models have been developed and computer programs written that allow the research men to begin at some point in the life of the stand and simulate its growth through years of time in a few minutes to give encouraging approximations of actual conditions.

(121) Objectives of a study at Louisiana State University are:

(1) to compare the results of four methods of thinning applied to a slash pine plantation, and to determine which is silviculturally or financially best; and (2) develop an objective measure of stand density and of thinning intensity. Results have led to the conclusion that no one of the thinning methods used showed any silvicultural advantage nor effects on tree quality. Although individual tree growth was stimulated, there was no difference in the overall net growth, in cubic feet, between the treatments. There is a definite financial advantage to thinning as long as the uncut trees can be made to grow at a rate faster than the interest rate applied to invested money. The competition index developed in this study is closely related with past growth and present crown growth. It is based on a measure of individual trees and their relationship, both in location and size, to the surrounding trees in the stand. The index can be used to advantage both as an objective measure of stand density and as an objective measure of thinning intensity.

(122) At Humboldt State College the project to investigate volume and growth of four hardwood species of the redwood region has produced two statistically sound volume tables for tanoak, (Lithocarpus densiflorus). One of these tables is in the customary form--relating cubic volume to tree height and diameter. The other table utilizes the "tarif system", recently introduced by Dr. Turnbull of the University of Washington, which proved reliable for tanoak provided the trees sampled for height are selected in proportion to their diameter. These

results should be of immediate interest to the timber industry in Humboldt County. The first table provides the industry with an accurate volume table in familiar form for estimating the volume of the newly merchantable species, tanoak. The second table has far-reaching importance, since it serves to introduce the faster, easier, and cheaper method of "tarif system" sampling to the timber industry.

(123) One project of Louisiana Polytechnic Institute deals with loblolly pine yield from the Chapman thinned plots at Urania, Louisiana. Field work was completed on needed measures of form class and taper. Data gathered over the past 34 years on these Chapman plots are being evaluated and analyzed for preparation of yield tables.

(124) In the Mississippi project on stem form of loblolly pine, the easily-measured variable of crown length did not give a satisfactory estimate of form class for a given tree. The penta-prism calipers with clinometer attachment proved highly accurate in measurement of outside-bark diameters at various points on the tree stem.

(125) Objectives of a Vermont project are: (1) to examine the variation in factors affecting the volume of the important timber species; and (2) to develop tree-volume equations and point-sampling factors for these species. Vermont loggers cooperated in securing measurements of over 300 trees on 27 logging operations. They delayed skidding, felled and bucked the trees while the researchers took tree measurements for stem analyses on the principal timber species of sugar and red maples, yellow and white birches, beech, and white ash. These data combined with 200 similar measurements made in a recent hardwood site study will become the basis for developing tree-volume equations for electronic computer processing. The equations developed will facilitate processing forest inventory data and the construction of revised volume tables for these species.

SITE

(126) In the Virginia Polytechnic Institute study of the parameters of site for certain tree species, soil mapping units proved of little use in predicting the rate of growth of yellow-poplar stands in southwestern Virginia.

(127) The Pennsylvania project on soil-site evaluation for black cherry and associated major species has brought out significant variations. The site index for black cherry was greater by 10

to 15 feet on northeast than on northwest slopes. The amount of shading by adjacent land masses and the slope position were also important in the growth of black cherry on northeast slopes. On southwest slopes the growth was closely correlated with texture and structure of soil than with topography.

(128) The Humboldt State College project to determine the relation between site indexes of redwood, Douglas-fir, and associated hardwood was completed. Original site curves were developed for the hardwood species: tanoak, Pacific madrone, and red alder. These were then related to the site curves for coast redwood and Douglas-fir. The site classification for Douglas-fir has been used to evaluate site for redwood before complete site curves became available for second-growth redwood. The site indexes of second-growth redwood and Douglas-fir showed a low correlation coefficient, that partly reflects the differences in site curves of the two species.

(129) The Humboldt State project to determine the influence of certain environmental factors upon site quality of young-growth redwood was completed. The data from this study did not provide good prediction of site quality of young-growth redwood even though several of the independent variables were significantly correlated with the dependent variable of site index. The Melbourne and Josephine soils have higher average site-index values than the other soils examined. Hugo and Mendocino soils are next, with Larabee and Caspar series least productive.

(130) Objectives of a Utah State University project are to relate site index to productivity, expressed as annual gross volume increment of uneven-aged Engelmann spruce-subalpine fir stands, and to predict annual gross volume increment from the following four stand independent variables: site index, cubic-foot volume per acre, basal area per acre, and basal area of average tree. Trees on 64 quarter-acre plots in this forest type on the University forest were measured in 1950 and again in 1964 to provide the basic data. Multiple regression analyses were made of the gross volume increment estimated from the four independent variables. Three separate analyses were made, one for each of three expressions of the site quality: (a) total tree height on D.B.H., with index at 20 inch D.B.H., (b) total tree height on age, with index at 100 years, and (c) total tree height on D.B.H. classes. The analyses indicate a strong correlation exists between the independent variables and gross volume increment. Moreover, they showed site quality "a" appeared to be the best of the three measures of site quality, on the basis of contributing the most to the total correlation. These promising data will be subjected to further critical analysis.

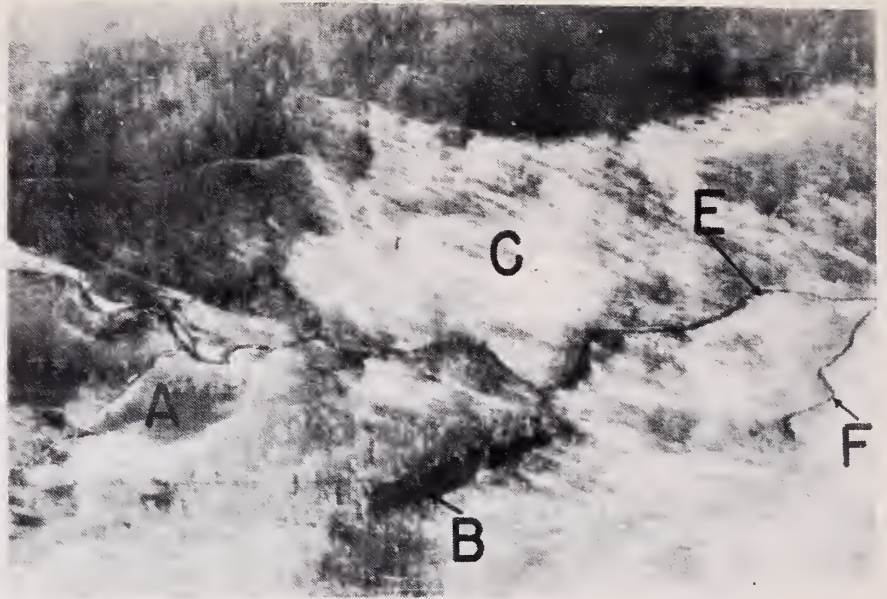
(131) In a project to develop an aerial volume table for central Oklahoma hardwoods, field work was completed with establishment of 150 one-acre plots. The data are currently being processed to construct a local volume table, to be followed by development of the aerial-ground relationships.

(132) The project at Minnesota on the development of an aerial photographic means of detecting and assessing dwarfmistletoe damage in black spruce forests has been completed. Dwarfmistletoe infection areas in black spruce forests were found to be easily identifiable through the use of infrared aero film. The positive transparencies produced by this type of photography show the healthy trees in purplish red, whereas the dead and dying infected trees appear bright green. A study of conventional black and white photography of the same area, flown in 1940, 1951, and 1962, resulted in a photographic technique which provided an indication, over time, of the change in area of the infection and the amount of timber loss on an average annual basis.

(133) The objective of a project at California is to determine the usefulness of thermal infrared (heat mapping) imagery in the inventory of wildland resources. Often through this technique unique features suitable for recreational development such as hot springs and caves can be located in vast wildland areas quickly, accurately, and economically. Hot springs with promise for recreation, or even production of thermal electric power, usually are not detectable on conventional panchromatic or infrared aerial photography because their light reflectance is essentially the same as that from cold water springs. Thermal infrared sensors, however, record differences in temperature rather than reflectance; often this permits hot springs to be differentiated from cold ones on thermal infrared imagery. Caves of potential recreational interest may be undetectable on conventional panchromatic or infrared aerial photography because their overburden of soil, rocks, and vegetation has the same photographic appearance as that of surrounding areas. Thermal infrared sensors (operating in the 8-14 micron band of the electromagnetic spectrum) record temperature differences of only one or two degrees Centigrade; consequently, the slightly cooler terrain associated with caves may be readily distinguishable from the surrounding terrain of normal temperature on thermal infrared imagery.



Panchromatic-Minus Blue
(0.5 to 0.7 microns)



Thermal Infrared
(7 to 15 microns)

Fig. 17 - Two contrasting aerial photos of forested land in the Sierra Nevada taken with different kinds of light reaching the film: visible on left and infrared on right. Two swamps at A and B look about the same by visible light, but infrared reveals the swamp at B is wetter than at A, by the black contrast with gray. Again, forest sites at C and D appear similar by visible light but infrared distinguished C from highly-productive site at D. Univ. of California F 2180.

(134) Identification of efficient sampling systems to serve desired standards under a variety of forest resource situations and management objectives is the objective of a project being initiated at Syracuse as a guide for timber inventories.

RECREATION

(135) A New York study at Syracuse University dealt with public campsites in the Adirondacks and Catskills. At campsites, the number of visits by campers showed little relation to distance from population centers. This differs from patterns reported on other studies in the literature. Possibly the New York State area embraces more heterogeneous social regions that complicate the physical and demographic factors of camper demand.

(136) Another project at Syracuse dealt with private investment in outdoor recreation. Firms studied in the recreation industry operated three types of facilities: shooting preserves, fishing preserves, and campgrounds in New York and four New England states. The objective was to learn industry characteristics and effect of public policies.

(137) A Purdue project has an initial objective of describing the outdoor recreation industry in southern Indiana. Personal interviews with operators of 109 outdoor recreation firms provided the basis for describing the industry as follows. The average recreation firm in southern Indiana was family owned, having investments less than \$50,000, expending annual operating costs of about \$6000, returning an average conversion surplus of \$2700 and returning a net residual income to labor and management of \$1067. Only 20 firms produced "conversion surpluses" of \$5000 or more. Fishing lakes comprised half of the enterprises, with multi-activity areas and swimming lakes making up another 25 percent. Hunting, cabin rental, boating, camping, horseback riding and picnicking were other activities featured. Multiple regression predictions of profitability, expressed as conversion surplus returns, provided equations with R^2 values in excess of 70 percent. Independent variables measured location and accessibility of the firm, site characteristics, financial inputs for investment and operation, personal characteristics of the operator, and size and capacity of the area. An urban web index, a distractions index, a developments quality index, and a simple subjective evaluation of the operator were introduced. It was concluded that southern Indiana has large obstacles to overcome before it can capitalize on its natural recreation advantages. The income generated by the existing firms is not thought to have provided much economic impact on the economy of southern Indiana. Each customer is an average receipt of \$1.39 to the recreation firm. However, the local origins of the customers indicated that there was little injection of outside tourist dollars into the region through these commercial firms.

(138) A Delaware study seeks to measure ecologically the impact of urbanization on small wildland areas. Natural hardwood areas are fast disappearing due to increasing pressure of urbanization on previous farmlands. This disappearance amounts to half the number of small wooded areas present in 1954. In the remaining woods, garbage and trash dumping along with tree mutilation and removal reflect the current public usage. In a protected woodlot, studies have progressed one year on plants and animals as indicator species to help evaluate the urban impact on woodlands. In a 34-acre woodlot, 100 kinds of birds and 13 kinds of mammals were recorded; squirrels and mice were trapped, tagged, and released for continued study in the woodland community.

(139) In a Maryland study of forest land diverted from forest production to recreational interests, surveys of resident and non-resident forest ownerships have provided data for analysis.

(140, 141, 142) Study of the importance of public and private forests in outdoor recreation in Louisiana has involved three McIntire-Stennis projects. Significantly, more landowners of 5000 to 16000 acres lease their lands for recreation, usually hunting, than any other size class. More than three-fourths of the State's large forest tracts over 5000 acres are available to the public for outdoor recreation. The large landowners show greater willingness to share forest recreation opportunities with the public. They favor leasing their lands to the State

for game management for a nominal fee. This makes the lands available to the public and transfers to the State administrative responsibility for their use as public hunting areas. It suggests that broader leases for compatible forest recreation, such as camping and picnicking, might also be developed in the future with State agencies. Forest landowners complained of lack of responsibility on the part of the using public, citing as important problems the careless and willful littering of camp areas with garbage and increased incidence of forest fires during peak use periods. Preliminary findings on forest recreation in State parks and forests indicate the need for further information on places of interest in the vicinity of the recreation areas. This has been brought to the attention of appropriate State agencies.

(143) A University of Michigan study seeks to develop a quantitative measure of the relative importance of features of State parkgrounds in attracting visitors. About 65 percent of the variation in numbers of visitors to campgrounds in Michigan State Parks has been accounted for by such variables as quality of state park, distance from major highway, distance from major city. These results are preliminary to further analysis. Successful development of an index of attractiveness will permit better assessment of the probable number of visitors to each park in future years and contribute toward better location of state park camping facilities.

(144) A Minnesota project will come to grips with problems of what happens to the forest in Itasca State Park when managed as a wilderness forest park on a purely protection basis. Preliminary results indicate that the very attractions which the Park was created to protect tend to disappear because of the protection policy. Park users rated the aesthetics of the old-growth red pine stands as the number one attraction even ahead of its uniqueness as the source of the Mississippi River. See Table. Red pine is a species which requires fire to assist it in reproducing. Under park management, the exclusion of fire plus damage by heavy deer population, built up when no hunting was permitted before 1945, have precluded regeneration of red pine in the pure red pine stands. Obviously, it would be intolerable to permit wild fires to burn unchecked. This study seeks alternative measures to assure red pine stands for future park visitors. Such measures as controlled prescribed burning, phytocidal control of weeds, logging with surgical finesse, and artificial seeding and planting will be evaluated for effectiveness, ecological soundness, and public acceptance.

Itasca Park Visitor Preference, July 1 - September 15

Preferences arrayed by schedule --	First choice (N=600) Percent	Second choice (N=600) Percent
<u>Major Attractions</u>		
Forest vegetation, natural beauty	39	32
Headwaters of Mississippi	37	14
Park facilities	18	25
Lake scenery	2	9
Nature study, & other	4	6
No response	0	14
Totals	100	100
<u>Leisure-time Activities</u>		
Sightseeing	76	11
Swimming	3	15
Fishing	8	8
Hiking	5	9
Picnicking	2	11
Canoeing, boating, & other	6	46
Totals	100	100
<u>Vegetational Preferences</u>		
Red pine	36	10
White pine	7	26
Red & white pine	24	4
Birch	3	16
Spruce, fir, other	7	14
No response	23	30
Totals	100	100

(145) A project on forest-recreation investment in Iowa is evaluating the effectiveness of public programs. One promising way of meeting some of the increased demands for local outdoor recreation facilities is through local action, such as Iowa's County Conservation Board Program. That the program is popular and is effectively meeting needs is indicated by the development of conservation-board outdoor-recreation programs in 75 of Iowa's 99 counties during the first nine years. Financed by a special county tax, annual budgets had grown to over three million dollars in the same period. The kinds of areas vary from 5 outdoor classrooms to 104 river accesses and 125 parks.

(146) Use of recreational facilities is the subject of two Utah projects. One on campground use has just completed collection of data for analysis.

(147) The other project is progressing into its second year on the recreation visitor use based on number of cars in a complex at any hour. The

sampling technique, developed during 1964, which indicates use on an hourly basis for each recreational unit or site within an entire recreational complex, was modified in 1965. On weekends, the traffic in Logan County reaches a peak soon after noon, whereas on holidays the peak is during the mid-morning. This pattern is similar for the two seasons. Frequency of individual site occupancy is to be programmed, and it appears that it will be possible to predict use for specific sites.

(148) University of Montana projects on forest recreation deal with developing a descriptive inventory of forest recreation, and the detailed study of the recreational users by specific areas. One such study already completed deals with user opinions on Wilderness Areas.

(149) An Idaho project deals with methods for estimating recreational visits and use on unattended recreation sites. The development of an instrument, both low in cost and efficient, was completed in the fall of 1964. This enabled on-site collection of data on numbers of visits and types of use by recreationists in northern Idaho State Parks. The counting devices underwent testing during the 1965 recreation season, and resulting data are currently under analysis.

(150) A University of Washington project on recreational use of forest land is in the preliminary stage.

(151) A Washington State University project deals with the recreational use of a multiple-use research area for the purpose of developing guidelines for recreation management. Recreational use of the study area is heavily concentrated during a five-week big-game hunting season. Hunter camp distribution is strongly related to the location of a game preserve, to road access, and type of vehicle used. For the most part deer hunting was by day-visit hunters, but elk hunting attracted both camper and day hunters. The study has included observation of recreation use and interviews with hunters. The area was closed to public entry by the County Commissioner July 5 to October 15, which severely curtailed summer recreation use.

WILDLIFE

(152) At the Storrs Agricultural Experiment Station in Connecticut, the results of 5000 ovarian and 9000 uterine analyses have been obtained from game biologists in states east of the Mississippi River and Nova Scotia. Related data on latitude, physiology, soil types, land-use patterns and other factors are being obtained to determine their effects on deer multiplication. Some preliminary analyses already have been completed.

(153) A research project is underway in Maine to measure the influence of deer herds of known size on forest vegetation. A thorough vegetative analysis of an 80-acre island was made prior to release of deer. Repeat photos will be made in future years to record changes in the vegetation caused by the browsing activities of the deer. Three permanent fenced

deer enclosures were erected in three vegetation types. Then browse samples of trees and shrubs (spruce, birch, maple, mountain ash, etc.) were analyzed for protein, fat, fiber, ash, nitrogen-free extract and carotene content. An experimental solar battery-powered radio transmitter was built and is being tested to measure deer movement.

(154) Scientists at Rhode Island have developed an electronic device for locating deer to which radio transmitters have been attached. The transmitter on the deer sends out signals which are picked up at a central point and re-broadcast to field personnel. This permits them to track deer with conventional portable radio equipment. Time previously used in initially locating the animals can be spent in tracking them. Six samples can be taken for predetermined time periods. A linear arrangement of these sensors creates an electronic barrier which a transmitter-equipped deer cannot penetrate without detection. The system promises to be useful in studying the movements of wide-ranging birds and migratory animals.

(155) A study in New Mexico is designed to determine how preparing a range for livestock affects abundance and distribution of mule deer. Information also is being obtained on the influence of season, slope and exposure and water availability on range used by deer. It has been determined that the deer stay mostly around water and shift to different areas when the water is depleted. In the well-watered areas, the average density was six deer per linear mile, whereas in the areas with no available water, the deer averaged only 0.3 per linear mile. The browse plants of the area consist of juniper, oak brush, and sumac in abundance, and a scattering of mountain mahogany, apache plume, and four-wing saltbrush. Deer apparently graze all these plants. Incomplete counts indicate that 65 percent of the juniper have been browsed, 40 percent of the oak, and 29 percent of the sumac. Around permanent water, deer use of all the plants was heavier. Browsing showed some degree on all of the juniper and sumac and on 50 percent of the oak.

(156) A new project on elk ecology at Humboldt State College will integrate the data from the study started in 1956 on elk population in the Prairie Creek Redwoods State Park region.

(157) In view of projected increase of our present human population, greater opportunities for hunting must be afforded from a shrinking forest land area. Scientists in Georgia are attempting to learn how rabbits fare under different management conditions. Large enclosures of 100 acres are used to determine the effects of supplementary winter grazing and natural enemies on rabbit populations. The study so far has revealed reproductive curtailment and parasite problems must be solved if increased demands of sportsmen are to be met.

(158) Research also is underway in Georgia on how quail respond to changing environment and how wildlife managers can improve quail habitats. Comparisons are being made of quail populations in pine plantations, natural forested land, abandoned fields, and manipulated habitat--controlled burned for forest and game protection. Use is made of some

data available from previous studies on breeding populations and fall covey size and composition. As vegetational changes occur on the selected Coastal Plain and Piedmont sites, their effects on quail populations are being determined. Dyeing and trapping techniques have been perfected. Initial evidence of food preferences has been obtained.



Fig. 18 - University of Georgia wildlife biologist testing radio-tracking equipment on a bobcat. This method is used to determine the effects of low-level radiation on predators of rabbits.

(159) Scientists in Connecticut are initiating research on the relationship between oxygen concentrations in water and brown trout development. Measurements are taken on trout growth in water with fluctuating daily oxygen content, and the oxygen consumption of the fish.

(160) One study at Louisiana State University deals with the influence of the wood rat on oak regeneration. The condition of gonadal development was obtained from 9 wood rat specimens. Warbles were noted in the gular region of the neck of two of the 9 specimens. Over 1000 squirrels were examined for warbles but none was found. Four transects 132 feet wide and approximately one mile long in two different vegetational types

were checked for wood rat nests. There was an average of 0.48 dens per acre; however, the transect in the area having the most dense ground cover averaged 2.2 dens per acre.

RANGE

(161) The use of forested lands for summer grazing by domestic livestock is important in the mountain West, where private ranches often adjoin forest land. A University of Montana study aims at obtaining information on both the biology and economics of forest grazing by cattle. The first phase has focused on clearcut areas, where it has been found that the presence of introduced grasses, especially Kentucky blue-grass, is an attraction to livestock.

(162) Range research dominated two McIntire-Stennis projects in Wyoming. One concerns plant-animal-soil-climate factors definitive of the juniper type of northern Wyoming. Herein, a deer-proof enclosure evaluated the influence of these animals upon juniper and associated plants; chemical-control treatments test response of understory vegetation; and small mammal trapping indicated fauna in the Rocky Mountain and Utah juniper communities, which resembles fauna of juniper communities of the Southwest.

(163) A study on woodland encroachments focused on microclimatic differences during summer of 1965 between stable and unstable forest margins of lodgepole and limber pine. Both soil moisture and soil temperature decreased with depth. Soils were moister at the edge of mature trees, in the stable margins in June, in the unstable margins in August. Soils were warmer with increased distance from mature trees to margins, and, in the stable margins, compared to the unstable. Temperatures at soil surface were higher on the unstable than the stable sites both in the mature trees and, in August, on the margins. In lodgepole and limber pine both maximum and minimum temperatures were higher on the unstable sites than the stable sites both in the mature trees, and, in August, on the margins. Finally, both maximum and minimum temperatures were less extreme in the mature trees than outside.

(164) An Idaho project reports on woodland-shrub-grazing lands. The western juniper type in southwest Idaho is enlarging at the expense of sagebrush-grass range. Unlike reinvading areas that it formerly occupied, western juniper is claiming new territory. No evidence has been found to suggest that western juniper formerly occurred in the sagebrush type presently being invaded. Mature juniper stands are confined to rocky outcrops and ridges. Individuals are gnarled and several hundred years old, and the interspace between trees supports only scant cover of shrubs and herbs. On the other hand the juniper stands moving into the sagebrush range are considerably younger; stand density and stature decrease with increasing distance from mature stands on the ridges. Determination of age by ring counts shows that this movement has been continuous during the past 100 years with a high proportion of the invading trees in the 30-40 year class. Whether the drought of the thirties was the primary or contributing cause for the rapid expansion of the western juniper type has not been established.

(165) A New Mexico project reports on vegetative changes under live-stock grazing following protection and comparing economic returns on neighboring ranches. Blue grama plants which have not been grazed since 1952 on the Fort Stanton Range produced more herbage, taller plants, and more seed stalks than grazed blue grama plants. Species composition and total plant cover were similar on grazed and protected sites. Blue grama is quite resistant to grazing but it may be reduced in vigor and production by continued heavy grazing on these forest-related ranges. Feed is a major item of expense for ranchers. Next to feed, vehicle maintenance, gas, and oil were important expenses. Most of the ranchers in the vicinity depend on Forest Service allotments similar to Fort Stanton Range.

(166) An Arizona State College study deals with differences in trees growing along natural park borders from those of the adjacent forest. Measurable differences between ponderosa pine trees growing along natural park borders and those growing deeper in the forest are noticeable in terms of height in feet, diameter breast high (DBH) in inches and the ratio between the two. For example, trees 40-60 years old and 8-12 inches in diameter yield a "slenderness ratio", height divided by DBH, approximately 3.0. For the age and DBH classes mentioned, there is over-stocking when above 3.0 (forest-grown) trees, and inadequate stocking when below (open-grown). Also, the above classes the "slenderness ratio" delineated the boundary between the two tree types as they bordered a natural park. The extent to which a natural park might be enlarged is important in balancing areas for timber production and those for forage for both livestock and big game animals.

WATERSHED

(167) Snow catch in coniferous crowns is a new project of Washington State University.

(168) Increasing the yield of water by reducing trembling aspen and Gambel oak cover is the objective of a project in Utah. Vegetation control treatments have been applied but soil moisture depletion data have not yet been obtained.

(169) A Colorado project has objectives of assessing water quality of a forested mountain watershed, and the effects of different multiple land uses. Bacteria indicative of fecal contamination have been found at all 11 stations within a relatively unused mountain watershed. High counts of such organisms related to initiation of spring runoff and peak flows. Some contamination undoubtedly originates from domestic livestock, other may be from wildlife populations naturally occurring within the area. Ratios of several types of indicator organisms are being used in an attempt to distinguish sources of contamination. Recreational use of the watershed is being measured. One season's records show 5500 auto visits from May through September, with 15 percent of the visits occurring on three holiday weekends. The potential production of ponderosa pine, and associated vegetation that is predicted by preliminary multiple regression equations has been developed. Such predictions will be needed for recommending land use practices of maximum benefit on the experimental watershed and other similar areas.

(170) A Pennsylvania project deals with the influence of forest cover and timber harvesting methods on streamflow. Streamflow data collected on three Leading Ridge experimental watersheds during 1958-65 have been summarized and analyzed to determine the influence of the present, pre-treatment forest cover on water yield. Questions are logically raised on how well results from small experimental watersheds can apply and typify the region in which they are located. Accordingly, a comparison was made of the streamflow characteristics of the Leading Ridge watersheds with that of larger forested watersheds in the Ridge and Valley Region which had been gauged for a long period of time by the U. S. Geological Survey. Streamflow characteristics investigated were annual and seasonal water yields, flow duration, and number and size of daily peak flows. Results indicated that water yield from the small experimental watersheds was very similar to the regional average water yields and that the experimental watersheds appeared representative of the region.

(171) A Massachusetts project deals with (a) comparison of the hydrologic characteristics of hardwood and white pine stands, particularly in regard to stemflow and soil moisture use on different soils, (b) study of growth responses and soil moisture use in plantations thinned to various densities, and (c) investigation of climatic variables and their use in prediction of soil moisture depletion and relation to streamflow records. Results for neutron probe soil moisture studies in 1965 indicate that less moisture was used by hardwood stands in the early part of the growing season and that soil moisture recharge is taking place more rapidly in the fall. Substantial differences in stemflow characteristics of species were observed, red oak higher than white pine and both much higher than white oak. Hardwood stands exhibited considerably higher amounts of stemflow than the pine stands. In heavily thinned plantations soil moisture deficits were less, and substantial soil moisture recharge occurred during the growing season, indicating possible effects on summer water yields.

MULTIPLE-USE

Research projects dealing with more than one of the major types of management of forest land are included in the multiple-use on land-use alternatives group. Needless to say, this research should also be considered with that of related individual type of management and use: timber, recreation, wildlife, range, and watershed.

(172) An Arkansas project deals with alternative uses of Ozark upland hardwoods by conversion to better range forage or timber pines. The 1965 season was generally the establishment year. The range development tract was aerielly treated with two-pound-acid-equivalent of 2, 4, 5-T as the iso-octyl ester in $4\frac{1}{2}$ gallons of diesel. The tract is divided into three plots, one to be left to natural vegetation. Two plots were overseeded with tall fescue at the rate of 15 pounds per

acre, the first week of September. With the hope of increased or earlier grazing returns, one of these overseeded lots was also fertilized at the low rate of 20 pounds of P_2O_5 per acre. The phosphorus treatment of this plot will be repeated annually to maintain the fertility differential. Conversion of upland hardwood stands to pine appears one solution to land use. First the hardwoods must be removed. Used here was a metered tree injector with undiluted 2, 4-D amine for trees over 3 inches in diameter. This was followed with a tractor mounted mist blower using a low volatile ester of 2, 4, 5-T in oil for the smaller vegetation. This combination gave a good hardwood kill although all treatments were done somewhat late in July. Shortleaf pine 1-0 stock was planted for the conversion. The planting site was difficult due to tree tops and slash from the merchantable timber that had been previously cut, and the rocky character of the soil. The conversion appears promising as there are now 600 to 700 well-spaced living pine trees per acre.

(173) A Pennsylvania project deals with multiple-use land management on a wildland area. On the proposed Quehanna Wildlands Management Research Program, the research prospectus was revised and meetings were held with Quehanna area sportsment to illuminate local problems. A hunter-use survey conducted on the Quehanna Area during the 1964-65 hunting season was followed by a check on general recreational activity maintained through 1965.

(174) A Rutgers project aims to measure and evaluate multiple uses of wood, water, camping, hunting, and fishing on two New Jersey State Forests: Stokes and Bass River. Evaluation was initiated by concerted studies of camping, hunting and fishing activities during the 1964-65 season. The camping study was completed by additional on-the-site interviews of campers including an attempt to determine where and how campers spend their time. Comparisons by years and between the two different campgrounds was made. This study has provided valuable information to the State. During the 1964 deer season, names and addresses of 2,152 hunters were obtained at checkpoints established in two forests. Mailed questionnaires to these deer hunters gave a 60 percent return that permits meaningful analysis of this short-time but intense forest use. Differences and similarities were observed between the two forests sampled. A similar survey was conducted to sample the fishing activity in Stokes State Forest during the spring stocking season. A total of 890 fishermen names and addresses were obtained on site. Analysis of the 60 percent questionnaire return suggests several significant differences between this group and the hunter group on the forests sampled.

(175) In a Rhode Island project on developing forest land multiple-use potentials to point up the significance of forests and wetlands, an inventory of them has been undertaken. A graduate assistant used 1000 stereo-pairs of photos to delineate over 125 kinds of vegetation

types differing by species, composition, height, density of crown, and of shrub layer. Using vertical sketchmasters, a team of three students transferred detailed-type boundaries of each vegetation type to 36 U. S. Geologic Survey quadrangle maps of Rhode Island. The types delineated on the quadrangles were colored to emphasize important vegetation differences. Now complete inventory of the kinds, amounts and locations of forest and wetland vegetation in the state is available. A state program to protect and acquire salt marsh habitats has already made use of the inventory for location and acreage. Town planning agencies are using the maps to develop plans for land acquisition under the state program to obtain land for conservation and recreation purposes.

(176) A Vermont study aims to identify, measure, and determine the significance of the various uses of forested land under the range of conditions existing. Study of the multiple uses of forested land has succeeded in defining scenery objectively, and now this classification system serves to associate different degrees of scenic beauty with varying land values. It is necessary to identify and demarcate primarily mountain-centered forest regions for planning purposes. These regions are divided between watersheds, among counties or other planning associations. After defining uses and units, it is next necessary to identify and measure uses. In one selected Green Mountain forest region all uses of land are being identified and measured in that area. A questionnaire has been developed for hunters, hikers, etc.

FOREST UTILIZATION

When current and future needs in forestry are studied, they emphasize very strongly the key importance of research in utilization and forest products. While the variety of McIntire-Stennis projects in this field is wide, the forest industries and forestry as a whole would have much to gain from a strongly increased total effort. The greatest part of the research effort is in wood and bark structure and properties: physical, chemical, anatomical, mechanical. By contrast logging and engineering - another important area - is meagerly represented. The projects described in the following five subjects of Forest Utilization total 46 and have contributed to the research training of 52 graduate students. Classification of a project is not always easy, partly because initial and final stages of a project may be quite different, but each project is described here under only a single classification.

LOGGING

(177) A logging-cost study at Clemson indicates that rubber-tired skidders provide the best means for logging under adverse weather and terrain conditions. This study attempts to determine which machine studied is most economical and dependable. From the information gathered, it appears that factors such as skill of the operators, the quality of tractor maintenance, and aggressiveness of the woods crews are of more consequence for efficiency of the machines than the forest conditions, the volume of timber hauled per trip, the average distance traveled per turn, or the size of the machine unit.

WOOD PROPERTIES

Two McIntire-Stennis projects at the University of Maine deal with wood properties. (178) In one, the specific gravity of plantation-grown red pine is to be estimated. Specific gravity of the average tree in a red pine plantation 22-25 years old can be predicted from that of increment cores taken at breast height on sample trees in the stand by a regression equation. This offers a quick and inexpensive method for estimating the yield of a plantation in terms of dry wood fiber, which in turn offers a means of predicting pulp yields. (179) In the other project, on relating properties of Maine woods to product utilization opportunities, active phases are: surface properties of wood, the electro-mechanical stress rating of local species used in structural lumber, and productivity rates of forest harvesting equipment.

(180) A New Hampshire project on improved kiln drying practice for hardwood lumber through a better understanding of internal stresses caused by shrinkage of lumber in drying is in the phase on new strain analysis techniques. By means of a transparent plastic coating with special optical properties bonded to the end of a drying board, the development of strain has been observed. When stress is applied to the plastic coating by the drying board and this is viewed under reflected polarized light, the adhered coating exhibits a pattern of colored fringes which reveal differences in distribution and magnitude of strain in much the same manner as contour lines on a topographic map. The rainbow-like fringes are called "isochromatics" because each band of color represents points of equal difference in principal strain. This gives a continuous picture of shrinkage strain in the drying board, not previously available. For improved understanding of the drying process, periods of critical strain can be identified in a sample board, thus permitting more precise control of drying conditions, which could result in faster schedules and less degrade. See Figure 19.

(181) The behavior of wood which is restrained from normal perpendicular-to-grain swelling due to moisture increase is the subject of research at Massachusetts. Tests conducted with four species--basswood, sugar maple, hickory, and mossaranduba--have shown that when dry wood is increased in moisture content but restrained from normal swelling, the compression stresses are great enough to cause permanent set in compression perpendicular-to-grain. Samples of each species, originally at a nominal 10 percent moisture content, were placed in stainless steel restraining fixtures, raised in moisture content to the fiber saturation point, and reconditioned to 10 percent moisture content. After cycling, the restrained samples showed 3 to 4 percent smaller dimensions tangentially (parallel to growth rings) than matched controls cycled without restraint. Samples cycled through lower ranges of moisture content showed proportionately less compression set. Less compression set likewise occurred in the radial (perpendicular-to-growth-rings) dimension.

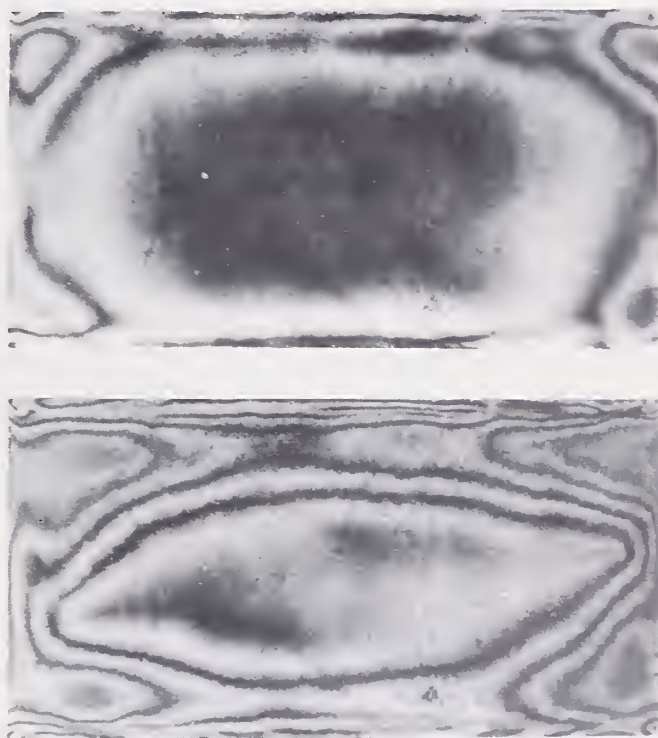


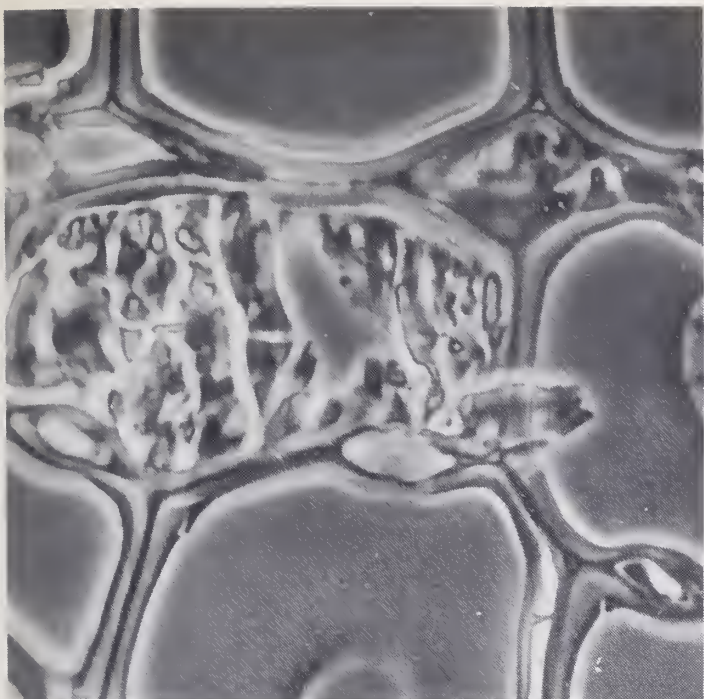
Fig. 19. These pictures show the end of a drying 2x6 red oak plank to which a clear plastic coating has been bonded to gain a better understanding of internal stresses caused by the shrinkage during drying. The "isochromatic" lines shown in the two photos are seen with reflected polarized light. Every point in the same line represents the same magnitude of strain developed in the board during drying. The two pictures, showing different degrees of drying of the same plank, illustrate the usefulness of this new method of study. University of New Hampshire project M-S-3.

Two projects at the State University College of Forestry at Syracuse University deal with wood properties in addition to one on wood quality of fertilized red pine (12) reported in the Soils section. (182) A completed project aimed to (1) identify the near infrared absorption bands characteristic of various wood components and (2) use monochromatic near infrared radiation to record photomicrographs of wood sections, the wave length of the radiation being deliberately selected as an absorption of a given wood component. Near infrared spectra of all carbohydrate wood components were recorded and most bands successfully identified. The spectra of the carbohydrate components were quite similar to one another and absorptivity coefficients for the various bands are lower than those in the infrared proper by a factor of 100. The foregoing results seem to exclude achieving the second objective. Because of low absorptivity, samples of millimeter thickness would be required, but samples of such thickness do not lend themselves to photomicrography.

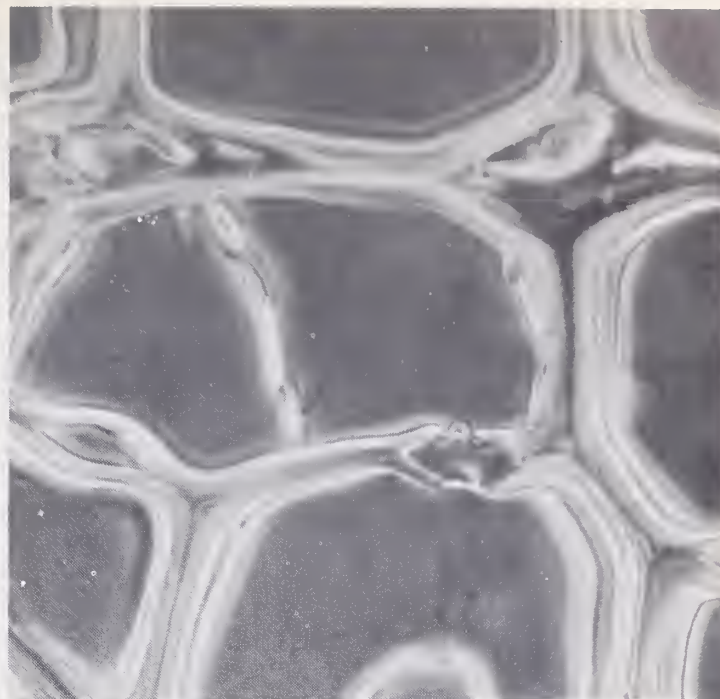
(183) Another project is on distribution, uniformity, and molecular properties of arabinogalactan in larch wood. Arabinogalactan is located in heartwood of western larch; its removal from the wood by extraction with water shows no volume change, so it must be extracellular. The polysaccharide could be visualized by phase-contrast microscopy of transverse sections of wood. This showed that it was deposited in the lumen of both spring- and summerwood-tracheids, in the ray cells, and in the epithelial cells lining the resin canals. Longitudinal sections showed few of the tracheids filled with arabinogalactan. The distribution of arabinogalactan in the trees is being studied in tamarack, western larch, and Japanese larch. Properties of arabinogalactans are studied by osmometry, sedimentation-diffusion, and equilibrium techniques, and molecular-weight distribution with fractional precipitation, gel filtration, and permeation. See Figure 20.

(184) A Pennsylvania study has sought to develop methods of quantifying the molecular alignment due to stress. Techniques to examine molecular structure change with load level have not been fruitful; however, equipment necessary to quantify this observation should be available in the foreseeable future.

(185) Current research at West Virginia aims to assess wood characteristics of black cherry useful on variation and heritability. Wood of black cherry varies both between and within individual trees growing on a uniform site. Examination of 50 trees indicated average specific gravity breast high ranged from 0.46 to 0.60. The average value, which amounts to 0.52, is considerably higher than the published specific gravity value of 0.47 for black cherry. The wide range of specific gravities encountered suggests the opportunity for selection of trees for either high or low specific gravity wood. Black cherry trees show two dominant patterns of variation in specific gravity along the radius at breast height. One pattern, similar to that in many hardwoods, shows



A



B

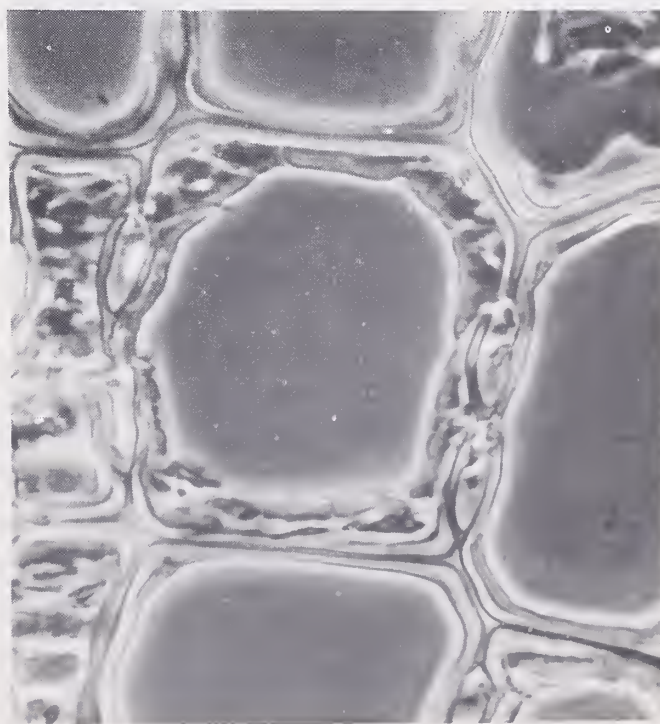
Fig. 20. Location of arabinogalactan, in transverse sections of heartwood of western larch.

- A - Arabinogalactan is seen in the lumen of the center tracheid, but not in the pit chamber.
- B - The same section, after washing with water.
- C - Arabinogalactan is present in the middle row of these summerwood tracheids.
- D - Arabinogalactan lines the inside of the cell wall of the central tracheid, and is also present in two of the pit chambers (to the right).

Light micrographs, phase contrast; 1250 x. College of Forestry at Syracuse University, project G.



C



D

specific gravity is highest in the central core and gradually decreases with approach toward the outside of recently-formed wood. Another pattern was found more frequently in cherry: Here, specific gravity is lower in the central core (10 rings), higher in the surrounding cylinder (15 rings), and decreasing gradually toward outside of the bole. In many of the trees this low density core showed abnormal coloration in the central heartwood; however, microscopic examination revealed no incipient decay. In the wood of leaning black cherry trees colorimetric examinations of thin sections of tissues on the upper side of the lean show the low lignin and high cellulose content that would be expected in tension wood. This phenomenon occurred even though the eccentric growth increments were on the lower side of living trees. No marked development of a G wall layer has been observed.

(186) The current project at the University of Michigan on wood extractives and adhesion will investigate location and chemical stability of certain extractives, particularly fatty acids and their compounds, in wood under varying conditions of temperature, moisture, pH, and time. In the initial stages, isolation techniques of the extractives are studied. Various methods of preparing ground wood for extraction have been compared, and several wood species have been explored for gross chloroform extract under various methods of preparation. Work is underway to separate the chloroform or ether extract into meaningful groups of compounds by use of thin-layer chromatography.

(187) Research in Missouri is designed to contribute to fundamental knowledge of wood structure and properties of commercial tree species as related to different kinds of growth, either abnormal or normal. Various types of "shake" -ring, wind, etc.- found in commercial woods cause rejection of otherwise usable logs or lumber. This year some 10,000 butt logs of oak and walnut were evaluated as to the amount and type of shake defects. In addition, samples of walnut which exhibited ring-shake were studied in the laboratory to determine what characteristics of their anatomical makeup could be associated with shake. Red-cedar is an important species to the large cedar novelty industry in the Lake Ozark region. Some 80 cedar trees were sampled by increment cores to indicate wood-quality--specific gravity, extractable content, growth rate, etc.--of this species.

(188) Iowa State University scientists are investigating cell-wall structure of tension wood in silver maple trees. They are seeking relationships between the anatomy of this undesirable tension wood from the upper side of leaning trees and the degree of lean. They found that the abnormal cells (gelatinous fibers) of a tree leaning 20° have the normal sequence of primary, S_1 , S_2 , and S_3 cell-wall layers, plus the typical inner gelatinous "G" layer of tension-wood fibers--a thick layer that is poorly attached to the rest of the wall. Corresponding cells from a tree of only 10° lean differed in: the S_3 layer was rarely present, and the G layer was solidly attached to the rest of the cell wall and was only half as thick as in the tree of greater lean.

(189) A project at Montana deals with the variability in the wood of western larch, an important timber tree of the Rocky Mountains with wood-use potentials. At present this investigation focuses on the water-soluble extractives of larch wood and comparative micro-anatomy of western and subalpine larch.

Two projects at Washington State University deal with basic properties of wood. (190) One aims to relate the piezoelectric (or voltage-pressure) effect as a fundamental wood property to the causal strain, and as observed in a dynamic system. The piezoelectric effect of wood reflects the mechanical strain which results from impact on lumber specimens. Thus, as the strain propagates down the lumber, its presence may be detected by the piezoelectric charge which is developed; also, the rate of propagation of this strain wave is a reliable indicator of the static elastic modulus of the lumber in flat-wise bending. Results suggest that wave propagation and the piezoelectric effect may be combined in a useful nondestructive test for the elasticity of wood products. The piezoelectric effect illustrates polarity: the electrical signal generated may be positive in one area on the wood specimen and negative on another. See Figure 21.

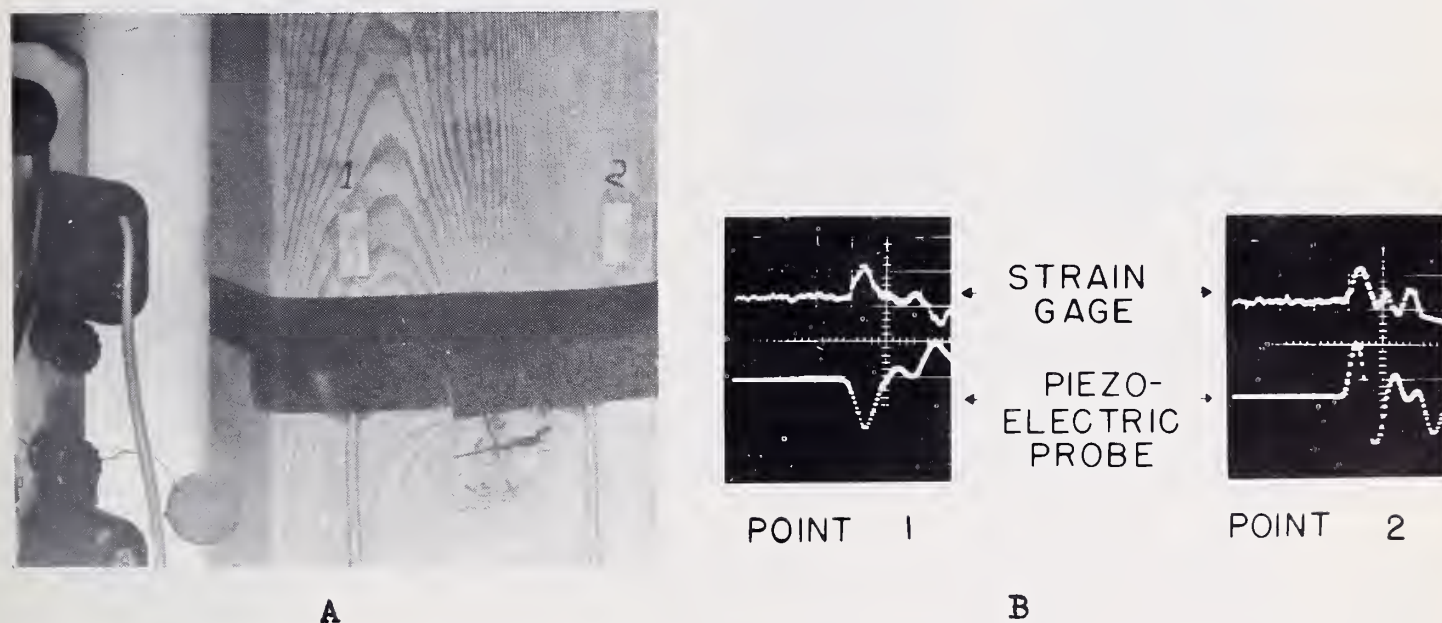


Fig. 21. An impact to a piece of lumber has been found to set up an electric charge, or "piezoelectric effect", in the wood which is related to the strain set up in the wood. In photo A, strain gages have been placed at points 1 and 2; piezoelectric probes were also attached at the same points. In photo B, oscilloscope tracings show how strain and piezoelectric effect may be related. Difference in piezoelectric response may be due to differences in wood microstructure. Possible non-destructive strength testing application is being studied. Washington State University project 1772.

(191) The second study deals with moisture in wood at high temperature. Adsorption relationships of grand fir were established at 100°, 130°, 150°, and 170° C. for a range of wood moisture contents from zero to fiber saturation. In the relative vapor pressure range from 0.0 to 0.6, as expected, hygroscopicity of wood decreased uniformly as temperatures increased; however, in the higher range from 0.6 to 0.9 the fiber saturation point increased with temperatures above 100°. This last unpredicted phenomenon was attributed to thermal plasticity of wood structure, catalyzed by moisture content. The plasticizing effect softened wood structure permitting inordinate swelling and increased accessibility of the structure to water. Inordinate swelling had no after effect on wood hygroscopicity. Sorption hysteresis, or lagging effect, was demonstrated in wood at 130° C.

(192) A University of Washington study dealt with effect of environment upon the quality of anatomical structure of Douglas-fir. Douglas-fir seedlings were grown under conditions designed to produce reaction wood. Techniques for anatomical study of this wood have been perfected and necessary equipment assembled. Volume of cells and cell walls have been enumerated from trees under varying environmental conditions. This information shows distinct promise of being related to other wood-quality features such as density and fiber length.

Three McIntire-Stennis projects dealing with wood properties are active at Oregon State University. (193) One deals with flavonoids extracted from bark that show promise as anti-oxidants to improve the quality of foods preserved by radiation. Two products of gamma radiolysis of quercetin from bark have been identified. Synthesis of model compounds has assisted in explaining resistance to gamma radiation. Analytical techniques and solvents to extract flavonoids are being developed to evaluate the major extractable compounds found in the bark.

(194) Another study aims to classify permeability of western hemlock wood by gas-flow techniques, and to relate findings to wood anatomy. Difficulties in treating and chemically processing western hemlock have led to problems in utilizing this species. Samples representing several important stands of hemlock have been collected. Apparatus has been designed and assembled to measure the flow of gases through carefully prepared wood samples. Measurements are proceeding with calibration methods developed to determine the wide range of variability.

(195) A third project is on variation in wood properties of important western conifers of different geographical races as related to environment and heredity. Both genetic factors and environment were shown to influence the specific gravity of trees in plantations originating from different geographical areas. Wood in trees younger than 25 years did not indicate reliably the specific gravity of mature wood. However, high correlation found between specific gravity of wood and date of bud bursting will be useful in selecting and breeding Douglas-fir.

(196) At Arizona State College research aims to determine the inter-relationships of age, environment and silvicultural practices on the wood of second-growth ponderosa pine in the Southwest. Preliminary evaluation of results indicates the following: (1) pitch and other extractives in the wood amount to about 150 pounds per cord; (2) greater amounts of extractives are found near the pith of the tree. This condition presents problems in estimating the true cellulose content by usual mensurational procedures; (3) the individual wood fibers increase in length up to an apparent fiber maturation age of 30 to 35 years. Also orientation of the microstructure of the cell walls of the wood shows continuing changes up to about 30-35 years. Both fiber length and microstructure orientation greatly influence the characteristics of the wood for lumber or pulp use. See Figure 22.

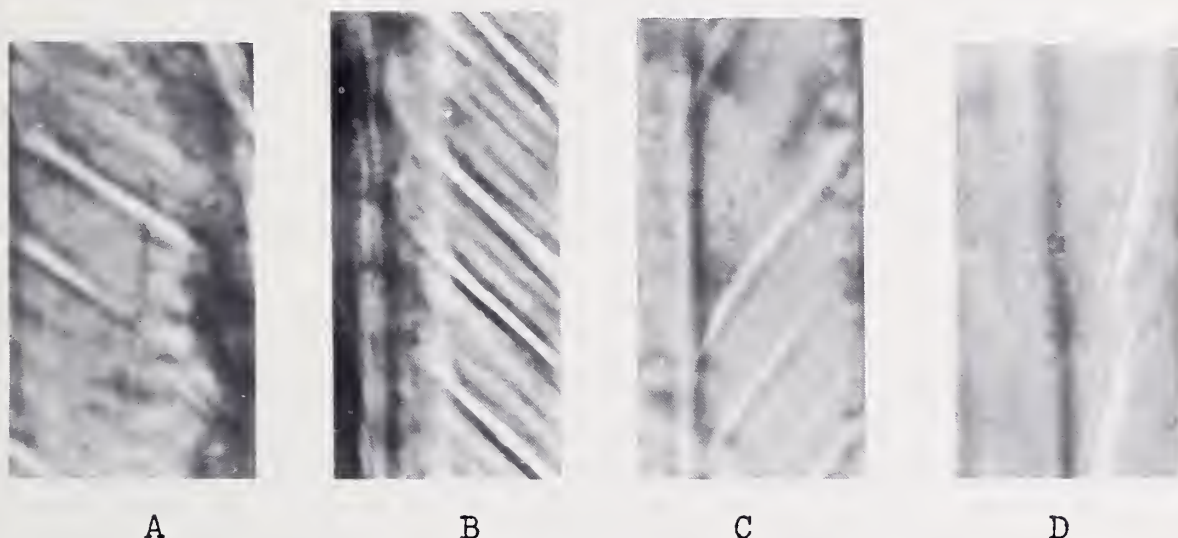


Fig. 22. Fibril angles in the cell walls of second-growth Ponderosa pine wood, Arizona State College project 2. The induced splits in the fiber (tracheid) wall have occurred between parallel microfibrils making up the fiber wall. The direction of the split reveals the angle of orientation of the microfibrils with respect to the long axis of the fiber. These angles, which influence fiber strength, are as follows in the four samples.

A - 55° , age 1 year.	C - $37\frac{1}{2}^{\circ}$, age 10 years.
B - 45° , age 5 years.	D - 12° , age 40 years.

(197) To determine the effects that climate, vegetative competition and soils have upon quality of loblolly pine, 5 plots have been established in Texas. Wood quality is to be measured in tree grades, fiber length, and specific gravity of the wood. Weather stations are in operation at each plot location, dendrometers are being installed, study trees were measured, graded and stand density recorded on the plots. Oversized cores from increment borings on the trees are now in the laboratory to study specific gravity and fiber length of the wood sampled.

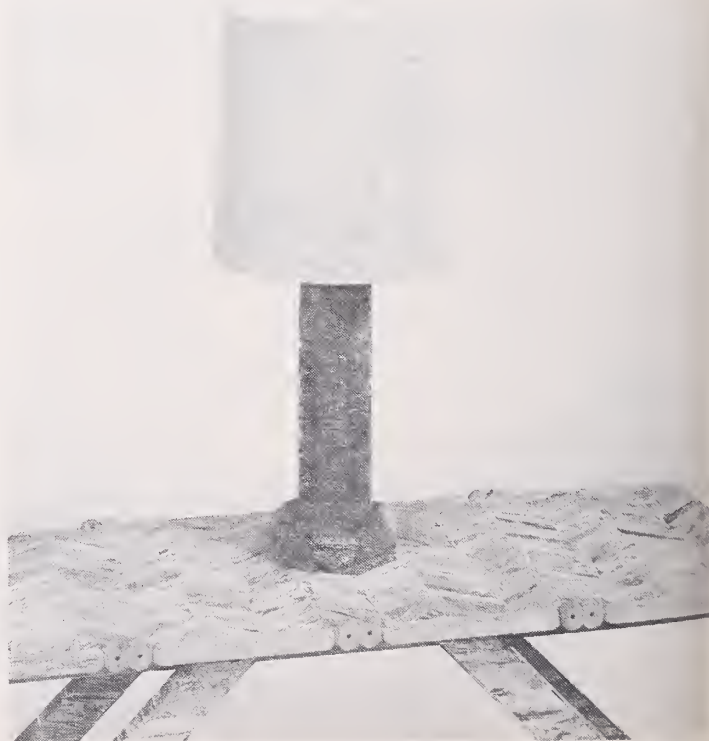
(198) In a study of wood properties of shortleaf pine in Oklahoma, cores have been collected from 41 plots and currently are under analysis.

(199) A Louisiana Tech project is testing pine and hardwood bark mixtures as mulch and soil conditioner for nursery grown and potted herbaceous and woody plants. Bark of different sizes and fertilizer treatments on roses during one growing season compared favorably with common mulching materials.

(200) A Mississippi project reports on radial shrinkage in loblolly pine wood. Shrinkage of the latewood increases with decreasing moisture content to a maximum at 10.8 percent at the oven-dry condition. In contrast, earlywood shows insignificant shrinkage. Green-volume specific gravities and percent of earlywood were directly proportional, and this linear relationship gives average specific gravity of the early and latewood. Green-volume specific gravity averaged 0.68 in latewood and 0.28 in earlywood, giving a ratio of 2.44 for the specimens studied. As earlywood percentage increased, volumetric, tangential and radial shrinkage decreased, but longitudinal shrinkage tended to increase.

Three McIntire-Stennis projects at Auburn University concern wood properties. (201) One is starting on figured wood--the rare grain pattern found in trees. (202) Another study is on the utilization of degraded hardwoods such as the "partridge wood", that is, red oak partly decayed by the fungus Stereum frustulosum. This has promising acceptance for interior decorative and ornamental furniture items. See Figure 23. (203) On a third project to develop methods of measuring anatomy of wood cells to investigate within-tree variation, micro-equipment and personnel are now ready to start.

Fig. 23. This coffee table and lamp base are made from "Partridge Wood". Large supplies are available of red oak wood in this attractive white-pocketed form, caused by partial decay by the fungus Stereum frustulosum. Auburn University project 906.



(204) A project in Georgia aims to determine acceleration of diameter growth in thinned loblolly and slash pine plantings and the effects on specific gravity, fibril angle, and stem taper. Will close spacing in loblolly pine plantations lead to stagnation, or can this species recover after thinning? Diameter measurements and core samples taken at varying heights in thinned stands show that loblolly pine releases after moderate stagnation. The trees, planted in 1933 and thinned 20 years later, exhibited a lag of two years before the growth was accelerated.

Two McIntire-Stennis projects at North Carolina deal with wood properties. (205) Mathematical description of the mechanical behavior of wood is the subject of one. Here, Hooke's law and its extension to linear visco-elastic concepts are being examined. Also emphasis is given to methods of solution of practical boundary-value problems in wood mechanics.

(206) A second project is on inherent wood property variations of tupelo gum important to the yield and quality of its wood. Important commercial species, including tupelo gum, show wood property variation within individual trees, between trees, stands, and geographical areas that is attributable to inherent genetic properties and environmental conditions under which the timber grows. Tupelo shows variation between stands. For instance, specific gravity of wood taken just above the butt swell ranged from 0.32 to 0.48. Such variability is meaningful in terms of the power required for machining, strength of the finished products, and yield. Such differences mean several hundred pounds in quantity of paper produced per cord of wood.

Similarly, average fiber length varies from 1.69mm to 2.02mm on wood from the 30th growth ring. Fiber length, likewise, influences the inherent strength of paper produced. In the most variable stands sampled, individual trees differed from 0.32 to 0.59 in specific gravity. Such differences point to the amount of gain possible by genetic improvement for either higher or lower average specific gravities.

(207) A project on wood machining at the University of California investigates problems arising from the mechanical conversion of wood. One problem studied is instability that leads to increased kerf, increased tooth wear, shorter saw life, and increased surface roughness. Circular saw instability results from thermal stress arising from the radial temperature gradient across the saw. Since the saw rotates at high speed and is very thin, a large fraction of the heat produced in cutting is transferred to the ambient air through the sides of the saw, rather than through the metal interior of the saw blade. Accordingly, the temperature of the saw drops very rapidly toward its center. Outside the cooler interior body of the saw its hot outer rim will tend to expand, wrinkle, or buckle laterally. The temperature gradient under several heat-producing situations has been determined, as well as the resultant stresses causing buckling in the outer rim. This buckling may be reduced by saw tensioning, heating the blade near the saw hub, cooling the outer rim, using a higher thermal conductive blade material, increasing the saw thickness, reducing rotational speed, or providing radial slots in saw plate near the outer rim.

A second problem studied is the surface finished in wood machining. Surface roughness was found to be related to the cutting mechanism and the anatomical character of the wood. A commercial surface recording instrument designed for use with metals was used to trace surface profiles of machined wood. For surfaces cut with a microtome, the surface roughness was directly related to wood-cell dimension; summerwood bands much smoother than for spring wood. To evaluate the effect of machining a surface indicator was constructed of a stylus larger than wood-cell dimension to filter out the micro-anatomical effects. The direction of grain, type of chip formed, depth of cut, and tool geometry were the most important factors in determining the surface roughness.

(208) A McIntire-Stennis project at the University of Minnesota evaluates how laminate size and moisture content influence shear stresses developed in glue lines, also, aspects of equilibrium moisture content. When two pieces of wood at different moisture contents are glued together, they will soon equilibrate to the same moisture level. This means that one piece of wood will tend to shrink while the other will tend to swell.

The result is that forces are set up in the glue-line area which can contribute to rupture of wood or glue. This study shows that laminate geometry and rate of moisture change are important for these undesirable interior stresses. The faster the change in moisture content, the thicker the laminates, and the wider the laminates, the higher will be the stresses developed. Also studied is change in the equilibrium moisture content which results from tensile stresses imposed perpendicular to the grain. Moisture-content increase was not proportional to elastic strain nor total creep, but to the fraction of creep which exposes new bonding sites, and was dependent upon the original moisture content of samples.

(209) The objective of a current research project at Purdue is to find accurate methods for mathematical analysis of mechanically connected wood-trussed rafters. The markets could be greatly expanded for these popular wood-building components, but improvements are requisite on the approximate designs available to the engineer today. Trusses built with rigid-type connections have been mathematically analyzed and computer programs written for economic use of these methods. The American Plywood Association has used this product of engineering research. The next major classes of truss to be analyzed are those made with toothed or nailed metal or wood joint plates. Satisfactory solutions are being developed on fundamental problems of joint behavior.

(210) Examining the feasibility of cutting thick veneer with a knife is the objective of a project in Pennsylvania. Production of laminae 0.25 inches thick has been achieved; however, the stress carrying capacity of the unit is considerably lower than sawn material. When a unit was produced with laminates of sliced material, its strength was comparable to that of units of sawn laminae.

(211) A project in West Virginia deals with converting low-quality sprout black cherry trees into dimension stock with a short-log, bolter saw. Current emphasis is on the amount of clear cuttings 2 to 6 feet long obtainable from trees containing no better than grade-3 logs. A total of 80 cherry trees, of quality that loggers would ordinarily leave in the woods, were felled, and marked into usual long-logs, which were graded and scaled to estimate yield under normal sawing procedure. Then bolts 3 to 6 feet were bucked from merchantable stems and larger limbs--cutting out and discarding obviously defective sections. The bolts were sawed into 4/4 inch flat stock and the boards graded for maximum yield of select-and-better material in furniture cuttings at least 2 inches wide and 18 inches long. Gross scale considerably exceeded that expected by normal sawing. The increase in yield from the bolter mill averaged 30 percent. It resulted primarily from a reduction in loss from sweep and taper, and increase was greatest in the smaller diameters. This promising production of select and better (clear one face) cuttings in random lengths over 18 inches, by 2 inches wide, by bolter mill will be followed by cost analyses.

(212) Better structural use of Appalachian woods is the objective of a Kentucky project. Strong trussed rafters can be fabricated in the form of simple triangular frames if the corners are fastened rigidly with fingered scarf joints. The elimination of web members or struts from a trussed rafter both reduces material and labor, and leaves attic space of a house free for use. Analysis of test data indicates that properly designed and fabricated fingered scarf joints are strong and rigid. This means that a triangular wood frame with such joints can be analyzed as an indeterminate structure with completely rigid corners. Such a truss has the interesting characteristic that if a uniform roof load such as snow ever becomes so great as to cause failure of the peak joint, the truss members will go ahead and sustain a load appreciably larger than that which originally caused failure of the peak. Less than optimal gluing conditions have been found to yield glue joints with structurally useful strength. Rough-sawn green oak with 41 percent moisture was glued with resorcinol glue, curing at room temperature with a pressure, except driving one 6-penny nail for each 4 square inches of glue line. Four days after fabrication, double shear specimens averaged 518 psi, and after drying to 6 percent moisture content, such specimens averaged 966 psi.

(213) The objective of a project at North Carolina State is to develop and apply an electronic system to record variables in circular sawmill sawing. A critically important problem in the sawmilling industry is the quantitative analysis of alternate production systems to provide a basis for making logical decisions on choice of equipment or processing systems. An exploratory analysis of 6 circular sawmills showed the need for an instrumented system of collecting production parameters. Of three electronic recording systems devised, the last prototype was effectively used in a pilot run in one sawmill. Currently an operating recorder model is being devised for use in the study. Successful development of such a technique may speed the development of standards in the industry and provide training aid for sawyers.

SEASONING, PRESERVATION

(214) Improvement of the present seasoning practices for large dimension wood products can be of economic significance to the wood-using industries. A basic study in Virginia is concerned with solving the general diffusion equation and comparing solutions with the temperature and moisture gradients in seasoning wood. A computer (IBM 7040) has been used to give solutions for diffusion equations in simplified situations.

(215) Determining the ease and practicality of gas phase treatments of wood to modify its properties is the objective of a project at North Carolina State. It was shown that inert gases such as helium become

distributed uniformly through the void structure of wood specimens 3 inches in diameter to 18 inches long in seconds to minutes in contrast to liquid penetration under pressure that has not become uniform in days. The distribution of condensable vapors such as pentane somewhat above the boiling point was about 25 percent complete in minutes, but required days to come to final equilibrium.

Two projects report no results achieved but research training for graduate students: (216) Southern Illinois University, on vibrational measures of moisture in wood, 1 graduate student, and, (217) University of Illinois, on penta-treatment and strength of Douglas fir.

PULP, COMPOSITE PRODUCTS

Two McIntire-Stennis projects on pulp and composite products are active at North Carolina State University. (218) One aims to related wood fiber characteristics to paper quality for loblolly kraft production. This is of utmost importance to industrial paper manufacturers from two aspects. One is the knowledge enabling the manufacturer to use the most appropriate type of wood fiber for every type of paper or board product. The other benefit is the identification of the most influential fiber characteristics critical in paper-making as goals for tree improvement programs. The results of this study to date have shown the overriding importance of characteristics relating to cell wall thickness.

(219) A second study is on the sizing of paper and paperboard, particularly with regard to the mechanism and measurement of the penetration of aqueous fluids such as inks. After development of a suitable temperature control procedure, a number of variables affecting the rate of penetration of aqueous inks through paper were studied. Temperature, pH, and viscosity of the inks had an important effect on penetration rate. Additional variables under study include ink composition and surface tension, contact angle of paper surfaces, nature of paper surface. An effort is being made to develop standard ink formulations and test procedures that will be useful in evaluation of commercial papers and in the development of improved sizing materials.

(220) A project at Auburn on wood as light aggregate in concrete has the following aims: Identify components of southern woods that retard the cure of wood particle-cement mixtures. Find how to remove or neutralize deleterious wood components, and improve the quality of wood-concrete products. Blue-stained wood promotes the setting time of concrete-wood mixtures, whereas partially decayed wood strongly inhibits setting. Decay organisms appear to attack structural components of wood, producing soluble by-products while stain organisms utilize soluble

constituents with little effect on structural components. Sugar and hot water extractive among other components extend the setting time of pine sawdust-cement mixtures. Blue-stained pine sawdust containing less sugar than the unstained sawdust of the same species promotes the setting time of the mixture by removing sugar and other extractive substances. Chemical treatment of the pine sawdust-cement mixture with 1.0 percent solution of calcium chloride promotes the setting time more than blue stain, and also equalizes the setting time of sapwood and heartwood sawdust-cement mixtures.

(221) The objective of a current project at Purdue is to find methods for design of particleboard so that its strength and stiffness can be predicted in terms of measurable mechanical properties of its ingredients. Wood particleboard, as a reconstituted wood product made on a wide range of characteristics in sheets, has found ready markets in furniture manufacture and in construction for sheathing and underlayment materials. For the next logical step, to advance this new product into more critical structural uses involving human safety considerations will necessitate more precise engineering knowledge. On this project existing mathematical treatments of materials are being supplemented and adapted to the need for mathematical description of stress and strain relations in particleboard. Advances that have been made in airframe and space vehicle design by modeling materials and structural components as fine-mesh frameworks appear to be useful, along with some of the newer methods of solving classical problems in elasticity. Current activity consists of synthesis and tests of mathematical workability of models suggested by literary search, supplemented and modified as needed to approximate particleboard. Completion of a model will be followed by construction of specific particleboards and mechanical tests to evaluate prediction by the model.

(222) A project at Oregon State University on high-yield sulfite pulps of red alder aims to determine optimum two-stage pulping conditions. Current utilization of red alder for pulp is low despite the fact this is a major hardwood. High-yield pulps, comparable in quality to present production at much lower yield levels, have been prepared and evaluated. Two-stage cooking followed by refining shows yields of 75 percent of the original weight of a light-colored, easily-bleached pulp. Optimum cooking schedules involving changes of acidity and alkalinity in the two stages have been developed, based on procedures insuring the retention of higher levels of hemicelluloses largely lost in present commercial practices. See Figure 24.

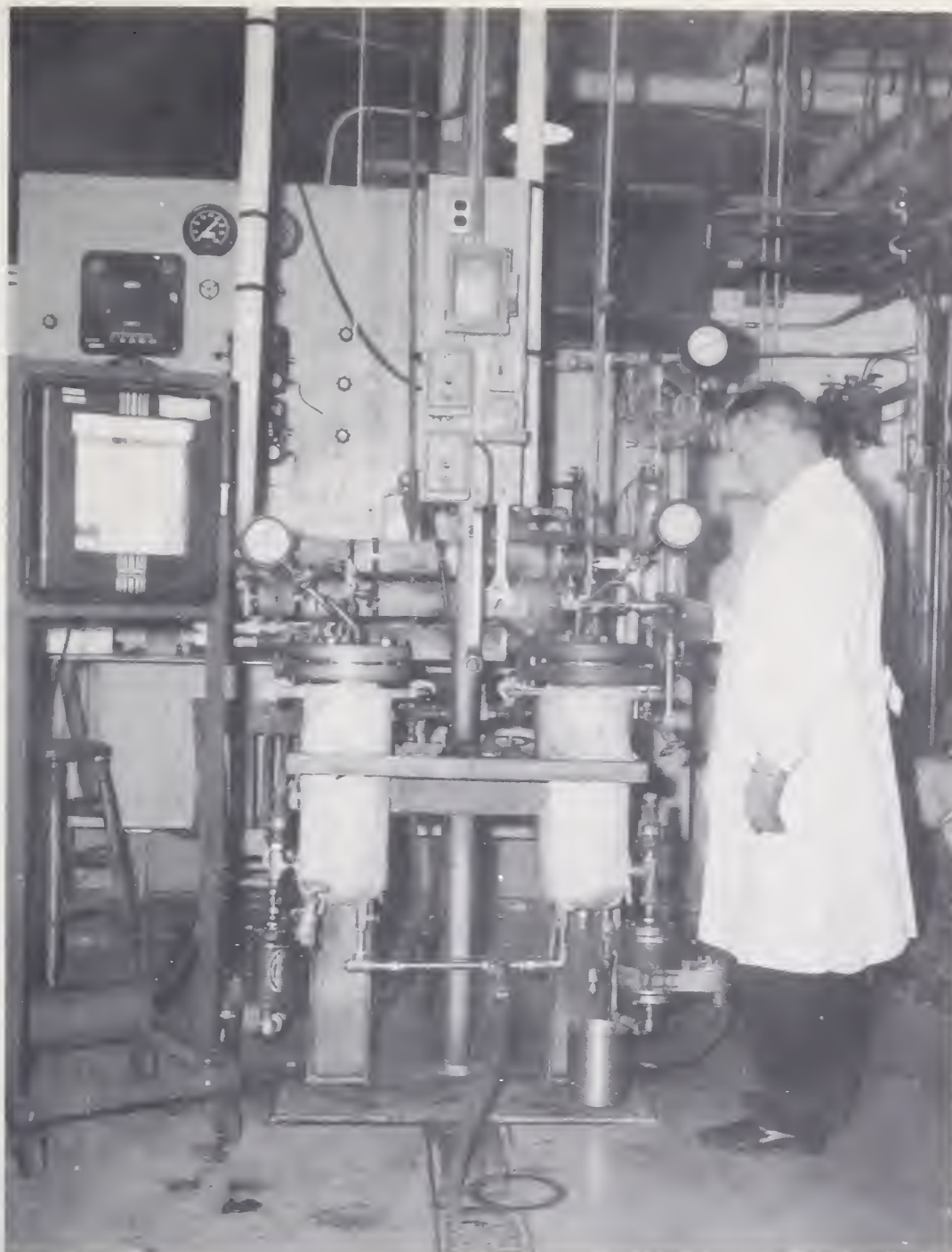


Fig. 24 - Twin stainless steel digestors with 2-pound charges of chips, used in developing high-yield sulfite pulps of red alder. The McIntire-Stennis project's use of this test-pulping equipment furthers the Oregon Forest Research Laboratory's contributions toward improved wood utilization.

FOREST ECONOMICS

Forest economics research in the McIntire-Stennis program deals with diverse subjects: public policies, the forest management enterprise, business opportunities and marketing problems. In all, 18 projects are underway. Their contribution of 11 papers prepared for publication, and research training provided to 20 graduate students are evidences of the activity reported in the following statements.

POLICY

(223) The objective of completed research at the University of Alaska was to examine the log export policies in effect on the forest lands of Alaska, and to explore the economic implications of possible modification of the policies. A program of controlled export of round logs from Alaska to the presently flourishing Japanese market might well be a useful management tool in more quickly utilizing stagnant, over-mature timber stands and creating new industry in the interior. *Present policies for both State and Federal lands restrict export of unprocessed logs of major timber species in an attempt to encourage the establishment of primary wood-processing plants as needed home industrial development. However, to date, most of the timber industries have developed in the rain forests of southeastern Alaska, while vast timber resources of the interior of the State have scarcely been scratched. There is an apparent strong demand in Japan for log species similar to those of Alaska. Should the policy be modified to allow controlled log export, perhaps on an experimental basis, a flow of logs to Japan would undoubtedly occur which could well be the catalyst for developing a new wood industry in Alaska.

(224) In one of the McIntire-Stennis projects on forest economics at the University of California appropriate operations research techniques are being explored to improve the efficiency in lumber manufacturing by providing information on inventory-control techniques.

(225) A second project at Berkeley is to estimate long-range timber supplies. Here, primary attention is given to developing a conceptual model useful for analyzing timber supply problems at regional, State, and national levels. Analysis was made of the North Coastal Region timber inventory by major ownership classes, by site class, and by timber stand characteristics to provide a basis for estimates of timber growing costs. Preliminary analyses on the effects of different schedules of future timber cutting on costs show that long-run costs of timber supply depend on three major elements: (1) the cost of timber growing programs, such as planting and stand improvement; (2) the long-term levels of timber growing which we may wish to achieve and (3) the

particular policies with respect to cutting to be employed until the long-term levels are achieved. During this transition period the policies to govern cutting might well aim at minimizing variations in gross receipts to the forest economy to provide the best basis for estimating production costs.

(226) The objective of a project under way at Southern Illinois University is to appraise the forest land taxation situation in Illinois and consider alternative methods, especially in view of possible land consolidation. Surveys have been made of 17 counties to analyze assessment procedures and estimate sales values of rural land in these counties. Also land-use maps are being developed for the 17 counties to permit of spatial analysis for taxation and land consolidation purposes.

(227) The project at the University of Michigan is to determine quantitatively the effects of various factors on industrial wood consumption throughout the world. Various prediction equations were developed utilizing data from 56 different nations where such data are collected. An index of wood availability was developed to assess the supply factors, and per capita income was used as an indicator of demand. Together these two factors in the equation forms developed were able to yield results granting coefficients of multiple determination of over .95. These equations should improve assessment of expected industrial wood consumption in the developing countries where detailed information is at present unavailable.

(228) A Missouri project on the feasibility of silviculture has been initiated, and one graduate student received research training.

(229) The objective of a project at the University of New Hampshire is to increase the adaptability of linear programming techniques and models for solving long-term planning problems of large forest-based industries. A Fortran computer program has been developed which will solve basic linear programming problems by an approach not new, though not widely used. In addition to being a starting point for adapting mathematical programming to comprehensive multistage forest management and timber production problems, this program shows promise of being useful to forest industries which have access to computers with only relatively small "capacities". This program will allow solution of more complex LP problems with such computers. Some methods of solving linear programming problems when "greater-than-or-equal-to" constraints exist require use of "artificial variables" that use up machine storage capacity. In the program developed no "artificial variables" are needed even for this type of "minimizing" problem.

(230) A study at North Carolina State University has the objective to identify and analyze forest policy developments of U.S. industry and public agencies and to formulate judgments on their probable impact on forest management. In some areas of forest policy the U.S. industry is a follower rather than a leader. The threats of public action in cutting practice regulation, for example, have apparently stimulated the forest products industry to intensify its activity in "tree farming" and in cooperating with the state governments in local regulation

of forest practices. In some other areas of policy the forest industries are taking a defensive attitude, for example, with respect to foreign trade restraints and local taxation. This study is revealing some of the policy developments in which industry and the public agencies may well cooperate more closely for the benefit of all. It is also evident that rational policy formulations require close coordination between different segments of industry, for example, engineers and foresters in tree improvement policy.

(231) The objective of a project in Virginia is to increase the efficiency of forest management decision-making through evaluation of theoretical decision-making models and application of the models to forestry problems. On the evaluating of theoretical models for recognizing uncertainty in forest management decision-making, preliminary results indicate that models are available which are compatible with the forest management environment. If empirical testing verifies these results, the efficiency of forest management decision-making could be increased significantly.

MARKETING FOREST PRODUCTS

A good representation of studies concerned with market channels and structure, market forces and performance, and market prices (supply, demand and utilization) have been initiated with McIntire-Stennis funds. They are addressed to clearer understanding of the market mechanism and its various functions, factors that operate against efficiency in marketing and pricing, and demand by type of wood and use prerequisite to improvements. The large number of species of trees differing in important wood characteristics, and the many unique purposes for which forest products are used and potentially can be used necessitate buyers for many types of products. There are not only markets for various kinds of lumber, but for many other products such as pulp, veneer, plywood, cooperage, poles, posts and piling. The market for forest products has not developed in efficiency and stability to the extent found for many commodities. Frequently market stability is lacking and prices for similar forest products in a given locality may differ greatly. This is especially true for timber sold as a lump sum on the stump. The economic problems of marketing forest products present significant facets susceptible of research attack. How efficiencies in the market mechanism can be realized deserves analysis. Spatial equilibrium models could well be constructed. Evaluation of the profitability of various marketing practices could help lumber producers to better reach the customer with products in the needed form. Marketing studies in the McIntire-Stennis program have been under way for too short a time to expect major findings as yet. Altogether 9 projects have reported progress and 8 graduate students have received training on marketing research.

(232) A project at Mississippi State University seeks information on the movement of lumber and the influence of retail lumber dealers and builder contractors on lumber use, species, grade, availability, and

marketing practices. The average Mississippi retail lumber dealer has been in business for 11 years, sells \$300,000 worth of merchandise annually, and employs from 8 to 12 people--depending on whether the business is a retail store only or whether it is also involved in building. Some 60 percent of the retailers are involved in building construction and repair. The most prevalent type of business organization is the corporation-50 percent, then individual ownerships-31 percent, and partnerships-19 percent. As would be expected, the larger businesses are commonly corporations, while private ownerships are frequently associated with stores located in small communities or having small sales.

Southern pine is the major species handled by retail yards, 66 percent. Western redcedar accounts for 16 percent of sales; other species are cypress, hemlock, redwood, spruce, Douglas-fir and hardwoods. Lumber retailers buy 71 percent of their lumber directly from the manufacturer; 72 percent of all lumber sold in Mississippi is manufactured by local wood industries. Over 90 percent of the lumber is kiln dried and surfaced, but only 3 percent has been treated with a preservative. Retail stores handle many non-wood items such as paint, insulation, tools, roofing, that make up 37 percent of total sales. The wood products percentages of sales are: lumber 31, plywood 13, and manufactured wood products 19. Home owners represent the largest customer group, accounting for 51 percent of total sales. Next is the builder-contractor who purchases 42 percent of the retailer's merchandise. His large purchases bring him favors of reduced prices and special credit.

(233) A project has started on market distribution patterns for lumber produced and major sources of lumber used in Louisiana. Questionnaires have been developed, lists of interviewees compiled, and interviewing has begun.

(234) On the study of requirements and distribution of wood products manufactured and used in Texas, the survey of sawmills has been completed. A total of 193 interviews include the entire industry. Sawmill data have been tabulated on punch cards and are currently being processed to provide a permanent statistical sample of the Texas sawmill industry. An additional study of lumber wholesalers, commissionmen, and brokers is underway.

Two McIntire-Stennis projects on marketing are active at the Vermont Agricultural Experiment Station. (235) One deals with lumber requirements and methods used in buying lumber for shipping and other non-manufacturing uses by manufacturers of other-than-wood products in Vermont. Results to date indicate that the use of shipping lumber by non-wood products manufacturers is small, probably not over eight million board feet per year. Practically all of this lumber is native softwood purchased directly from local sawmills. Consumers appear to experience no difficulty in obtaining the lumber desired in the grades and sizes desired. Improperly seasoned lumber was the most common fault cited by this group of consumers. Though consumption of shipping lumber is relatively small compared to other lumber uses, this market does constitute an outlet for the lower grades of softwood lumber manufactured in the State.

(236) Another project deals with present use of roundwood products on rural ownerships in Vermont and potential market for these products, emphasizing the utilization of sizes and species of growing stock for which markets are inadequate. Analysis of 1963 data shows that approximately one-half million cubic feet of wood was cut from small woodlands of Vermont for use as posts and poles by the owners. An almost equal volume was purchased from commercial dealers for rural farm and non-farm use. Over 95 percent of the total volume of cut and purchased roundwood was consumed on farms. Consumption per ownership averaged 150 cubic feet for farms and 2 cubic feet for non-farms. Whitecedar accounted for over 70 percent of the volume consumed.

(237) This project of Montana State University is completed in two phases: terms of sale surrounding the transfer of title from the manufacturer to the initial purchaser of Montana lumber, and distribution employed by Montana lumber products.

(238) A project is underway at Kansas State University to determine (1) the extent of the Kansas forest products industry in terms of volume by product and product flow and (2) the number of employees, dollar flow, and product destination. A directory of all firms and individuals involved in various marketing stages or processes--from producer to market agent to manufacturer--is being completed. In view of growing demand and lessening supply for hardwood products, such as walnut veneer logs and oak tight cooperage, timber data should be obtained to acquaint the producer with the situation and the future potential. Also the owner of woodlots, now 75 percent neglected in Kansas, should be informed of profit opportunities in timber production.

(239) A project at the University of Alaska will study potential markets and marketing procedures for the development and use of hardwood timber resources in Alaska's Susitna Valley. Marketing research can point the way to more intensive utilization through knowledge of the resource, quantity and quality evaluations, as well as potential products, marketing procedures, and markets. Cost and price analyses for woods and utilization operations, and product specifications and consumption trends for competitive timber products are also being formulated.

(240) A project at the University of California aims to improve efficiency in the redwood lumber industry by providing better information about future values of market characteristics. Preliminary models have been constructed and forecasting equations estimated for shipments and price.

Index of Universities and Their Statements

of Progress*

Auburn University, (Ala.)	39(904), 201(905), 202(906), 220(902), 49(903) 203(901)
University of Alaska	2(2-0236B), 223(2-0268), 239(2-0271)
Arizona State College	118(1), 166(5), 196(2), 44(3)
University of Arkansas	95(611), 172(610)
University of California	82(2351), 112(2349), 133(2180), 207(2181), 224(2353), 225(2350), 41(2179)
Humboldt State College, (Cal.)	7(3), 122(4), 128(2), 129(1), 156(5), 240(2352)
Colorado State University	169(312), 63(311)
Connecticut Agricultural Experiment Station	21(405)
University of Connecticut (Storrs)	152(340), 159(350)
University of Delaware	138(115-E)
University of Florida	19(1210)
University of Georgia	8(8), 23(3), 30(13), 31(14), 32(2), 35(6), 56(10), 73(9), 117(5), 157(11), 158(12), 204(1)
University of Hawaii	1(140), 14(139), 85(715)
University of Idaho	22(2), 101(5), 149(4), 164(1), 55(3)
University of Illinois	4(55-303), 6(55-360)
Southern Illinois University	71(64-R-4), 216(65-R-9), 217(55-334), 226(65-R-13)
Purdue University (Ind.)	40(1477), 72(1476), 113(1352), 119(1357), 120(1439), 137(1354), 209(1353), 221(1355)
Iowa State University	20(1582), 145(1580), 188(1583)
Kansas State University	74(672), 78(668), 96(671), 238(670)

* Alphabetical order, by States; the institution's own project number follows the serial progress statement number given in the report.

University of Kentucky	212(1015)
Louisiana State University	121(1169), 140(1177), 141(1188), 142(1232), 233(1233)
Louisiana Polytechnic Institute	84(MRP-2), 123(1), 160(1238)
University of Maine	17(6), 18(2), 97(1), 153(5), 178(3) 179(4), 199(3)
University of Maryland	34(L-100), 91(J-101), 102(H-83), 139(T-12)
University of Massachusetts	90(1), 171(2), 181(3)
Michigan State University	16(936), 28(979), 109(942), 114(978), 227(3)
University of Michigan	27(1), 106(2), 143(6), 186(9)
Michigan Technological University	52(2)
University of Minnesota	88(2252-S), 132(1934-S), 144(1935-S), 208(1932-S), 64(1937-S)
Mississippi State College	3(3-205-1123), 125(3-205-1120), 200(3-205-1121), 232(2-205-1124)
University of Missouri	26(522), 87(540), 187(535), 228(543), 58(534)
University of Montana	5(210: 1001, 1101, 1801), 83(210-302) 98(210-1604), 148(210-804), 161(210-603), 189(210-401), 237(210-202), 66(210-904)
University of Nebraska	79(20-23)
University of Nevada	24(512), 69(471)
University of New Hampshire	75(1), 110(4), 180(3), 229(2)
Rutgers University (N. J.)	174(256)
New Mexico State University	103(4), 111(3), 155(2), 165(1)
N. Y. State College of Agriculture (Cornell)	9(2), 45(1)
N. Y. State College of Forestry at Syracuse	12(b), 29(A), 134(I), 135(E), 136(D), 182(C), 183(G), 60(F)
North Carolina State University	205(9), 206(2), 213(7), 215(6), 218(5), 219(8), 230(3)
North Dakota State University	80(12-1), 46(1)

Ohio State University	10(1238), 36(4), 37(1), 62(2)
Oklahoma State University	115(1237), 116(1247), 131(1236), 198(1246), 47(1241)
Oregon State University	193(647), 194(763), 195(765), 222(764) 42(761), 43(646), 53(759), 57(760), 59(762)
Pennsylvania State University	15(1487), 94(1488), 127(1493), 170(1495), 173(1494), 184(1489), 210(1492)
University of Puerto Rico	93(1), 104(2), 105(3)
University of Rhode Island	154(953), 175(125)
Clemson University (S. C.)	68(709), 177(707), 48(704), 61(705)
South Dakota State University	81(420)
University of Tennessee	13(2), 70(1)
Texas A. & M. University	92(1526), 107(1525), 197(1527), 234(1524)
Utah State University	38(670), 77(658), 130(359), 146(669), 147(657), 168(641)
University of Vermont	76(1), 100(2), 125(4), 176(6), 235(3), 236(5)
Virginia Polytechnic Institute	126(3), 214(2), 231(1)
Washington State University	86(1770), 151(1848), 167(1849), 190(1772), 191(1775), 54(1771)
University of Washington	11(1), 25(6), 108(5), 150(3), 192(4) 67(2)
West Virginia University	33(1), 185(2), 211(3), 50 & 51(1)
University of Wisconsin	89(1264), 99(1263), 65(1262)
University of Wyoming	162(880), 163(879)

PUBLISHED RESULTS OF McINTIRE-STENNIS RESEARCH

Auburn University

Effect of blue-stained pine sapwood on the setting of Portland cement mixtures. T. C. Davis. In Manuscript

University of Alaska

The economic base and development of Alaska's Kuskokwim Basin with particular emphasis upon the period 1950-1964. Richard A. Berg. M.S. Thesis. 1965

Relationship of change in distribution and availability of nitrogen to development of highmoors in interior Alaska. Paul E. Heilman. In Press

Policy question: Should round logs be exported from Alaska? Frank W. Kearns. Inst. B.E.G.R. In Manuscript. 1965

Arizona State College

Fundamental cause of warp in second-growth southwestern ponderosa pine. Forest Industries. In Press

University of Arkansas

Preliminary tests on control of the pine sawfly. L. O. Warren. Ark. Farm Res. 14(2):16. 1965

Field tests for the control of the pine sawfly, Neodiprion taedae linearis, in Arkansas. L. O. Warren and Melvin Wingfield. Ark. Farm Res. 14(6):2. 1965

Controlling insect damage to young southern pine stands. L. O. Warren. Proc. 14th Ann. For. Symp. Louisiana State University. 1965

University of California

Thermal gradients--a factor in circular saw stability. Annual Forest Products Research Society Meeting. In Manuscript

Humboldt State College

Cubic-foot volume and tariff access tables for tanoak in Humboldt County, California. H. V. Wiant and W. S. Berry. Research Report #2, Div. of Natural Resources, Humboldt State College. 1965

The influence of certain environmental factors upon site quality of young-growth redwood. M.S. Thesis

The relation between site indexes of redwood and Douglas-fir and original site curves for tanoak in Humboldt County, California. M.S. Thesis

Colorado State University

Site-vegetation relationships in the montane zone of Northern Colorado.

J. M. Geist. M.S. Thesis 1965

Soil factors affecting ponderosa pine growth. B. P. Kayastha. M.S. Thesis. 1965

Germination of blue spruce and ponderosa pine pollen after eleven years of storage at 0° and 4° C. G. H. Fechner and R. W. Funsch.

Silvae Genetica. In Press

The microsporangium and microsporogenesis in Picea pungens Engelman.

G. H. Fechner. Am. Jour. Botany. In Press

Connecticut Agricultural Experiment Station

Respiration of leaves in light and darkness. D. N. Moss. Agronomy

Abstracts. In Press 1965

Capture of radiant energy by plants. D. N. Moss. Meteorological

Monographs 6(28):90-105. 1965

Storrs Agricultural Experiment Station

Significant Aspects of the Life Cycle of White-tail Deer in Eastern U. S.

Graduate Thesis

University of Georgia

Rough bark formation and food reserves in pine roots. L.W.R. Jackson and G. H. Hepting. Forest Science 10:174-179. 1965

Animal population determination problems of the wildlife biologist.

J. H. Jenkins. Bull. Georgia Acad. of Science. 23(2):48

Variation of morphological traits in clonal lines of slash pine.

William Beland. M.S. Thesis. 1965

The effects of transpiration suppressants on the survival and growth of pine seedlings. J. T. Paul. M.S. Thesis 1965

Plot sizes for timber cruising in Georgia T. E. Avery and R. K. Newton

Jour. Forestry. In Press. 1965

University of Idaho

Characteristics and preferences of recreationists in selected northern

Idaho State Parks. Howard R. Alden. Forestry, Wildlife and Range

Expt. Sta. Note 1. 1965

An injection probe for rapid placement of radioisotopes in soil.

H. Lowenstein. Soil. Sci. Soc. Amer. Proc. 29:328-329. 1965

University of Illinois

The Funk Forest Natural Area, McLean County, Illinois: woody vegetation and ecological trends. W. R. Boggess and J. W. Geis.

Transactions, Ill. State Acad. of Science. In Press

Southern Illinois University

A review of the literature on property and forest taxation. D. Baumgartner
and R. Nacker. Processed Manuscript. 17 pp. 1965

Purdue University

Moment resistance capabilities of 2" x 4" roof purlins lap-spliced over
a support. R. H. Perkins, A. C. Dale and S. K. Suddarth.

Purdue A.E.S. Res. Bul. 790. 1965

The analysis of wood trusses with nailed metal plate joints.

Errol D. Rodda, S. K. Suddarth and A. C. Dale. Amer. Soc. Agr.

Eng. Paper No. 64-917. Dec. 1964

Economic aspects of commercial outdoor recreation enterprises in Southern
Indiana. D. M. Knudson. Ph.D. Thesis. 123 pp. 1965

Economic aspects of commercial outdoor recreation enterprises in Southern
Indiana. J. C. Callahan and D. M. Knudson. 2 pp. Report.

Mimeo 1965

Outdoor recreation in Indiana. J. C. Callahan and H. Wadsworth.

Mimeo EC-292. 1964

The analysis of indeterminate nailed structures. Errol D. Rodda.

Forest Products Journal. In Press. 1965

Iowa State University

Photosynthesis, respiration and growth of forest tree seedlings in
relation to seed source and environment. G. E. Gatherum. Proc.

Central States Forest Tree Impr. Conf. pp. 10-18. 1965

Correlations among fresh weight, dry weight, volume and total length
of Scotch pine seedlings. J. C. Gordon and G. E. Gatherum.

Forest Science. In Press. 1965

University of Kentucky

Finger-jointed timber frames. G. Pincus, E. F. Cottrell, and
D. B. Richards. For. Prod. Jour. In Press

Trussed rafters with glued corner-joints. D. B. Richards. For.
Prod. Jour. In Manuscript

Louisiana State University

Public recreational use policies of owners of large private forests in
Louisiana. J. H. Lewis and R. W. McDermid. L.S.U. Forestry
Note #63. 1965

University of Maine

Forest stand factors affecting damage to eastern white pine, Pinus strobus
Linnaeus, caused by the pine leaf Adelgid, Pineus pinifoliae (Fitch),
(Homoptera:Adelgidae). R. H. Bishop. M.S. Thesis. 68pp. 1965

Chemical elements in complete mature trees of seven species in Maine.

H. E. Young and V. P. Guinn. Given at 3rd TAPPI Forest Biology Conference. Tappi. In Press. 1965

Preliminary tables of some chemical elements in seven tree species in Maine

H. E. Young, P. Carpenter and R. Altenberger. Maine Agr. Exp. Sta. Bulletin. In Press

University of Massachusetts

Relationship between salt concentrations in leaves and sap and the decline of sugar maples along roadsides. J.H. Baker. Mass. Agr. Exp. Sta. Bull. 553. 20pp. 1965

Effects on street trees of the use of salt as a snow control chemical.

F. W. Holmes. New Jersey Fed. of Shade Tree Comm. Ann. Mtg. Proc. 39:38-45. 1965

Salt injury to trees. II. Sodium and chloride in roadside sugar maples in Massachusetts. F. W. Holmes and J. H. Baker. Phytopathology. In Press 1965

Michigan State University

Selective sampling of indigenous Scotch pine plantation arthropods.

James Shaddy and J. W. Butcher. Bull. Mich. Acad. Sci. 1964

Variations in the foliar mineral content of five widely separated seedlots of Scotch pine. Klaus Steinbeck. Mich. Agr. Exp. Sta. Quart. Bull. 48:94-100. 1965

Foliar mineral accumulation of several Scotch pine (Pinus sylvestris L.) provenances. Klaus Steinbeck. Ph.D. Thesis 115pp. 1965

Relationship of selected terrestrial arthropods in chlorinated hydrocarbon use in Scotch pine plantations. J.W. Butcher and James Shaddy. Proc. N. C. Branch Ent. Soc. America. In Press 1965

University of Minnesota

Managing the vegetation of Itasca State Park. H. L. Hansen. Minn. Outdoor Recreation Res. Commission Report, Sept. 1965

Stress induced moisture content change of whole wood. Thomas B. Libby. M. S. Thesis 1965

Vegetational preferences of Itasca State Park visitors. R. Klukas and D. P. Duncan. Jour. Forestry. In Press March, 1966

Mississippi State University

Crown area of free-growing loblolly pine and its apparent independence of age and site. E. G. Roberts and R. D. Ross. Jour. Forestry 63:462-463. 1965

University of Missouri

Extent of shake in Missouri oaks. E. A. McGinnes, Jr. For. Proc. Jour. 15(5):190. 1965

Instrumentation for micrometeorological studies in hardwood forest stands. F. T. Holt and G. S. Cox. Proc. Missouri Acad. Sciences. In Press 1965

Shake in oak and walnut. E. A. McGinnes, Jr. Proc. Missouri Acad.
Sciences. In Press. 1965

University of Montana

A profile of lumber marketing in western Montana. Kent T. Adair.
Montana Forest and Conserv. Exp. Sta. Bull. No. 29, Missoula. 1965
Soil temperatures in the Lubrecht Experimental Forest. T. J. Nimlos,
R. W. Steele, G. M. Blake and R. D. Taber. Montana Forestry
Research Note #1. 2pp. 1964
The effect of position, age, and season on the foliar mineral content
of western larch (Larix occidentalis). M. J. Behan and W. Friedrich.
In Manuscript. 1965

University of New Hampshire

A modified linear programming technique applicable to forest and other
industries for computers of limited capacity. In Manuscript

Rutgers University

Preliminary report on results of camping study made in Stokes and Bass
River State Forests. Richard F. West. 13 pp. Mimeo. May, 1965

New Mexico State University

Costs and returns from forest management practices in New Mexico.
M. S. Thesis

New York State College of Forestry

Near infra-red spectra of carbohydrate wood components. William Schell.
M.S. Thesis.
Intra-specific hybridization in tulip-poplar. G. R. Stairs, and
J. R. Wilcox. World Forestry Congr. Special Paper. In Manuscript.
June, 1966
Environmental influences on patterns of wood deposition in red pine.
In Manuscript. 1965

North Carolina State University

Wood characteristics and kraft paper properties of four selected loblolly
pines. Part II. Wood chemical constituents and their relationship
to fiber morphology. Von L. Byrd, E. L. Ellwood, R. G. Hitchings
and A. C. Barefoot. For. Prod. Jour. 15(8):313-320. 1965
Wood characteristics and kraft paper properties of four selected loblolly
pines. Part III. Effect of fiber morphology in pulps examined at a
constant permanganate no. A. C. Barefoot, E. L. Ellwood and
R. G. Hitchings. Third TAPPI Forest Biology Conference Proc.
In Press. 1965

Current problems of the lumber industry. Lester Holley. 7pp. Manuscript. July 16, 1964
Forest policies of private enterprises. J. O. Lammi. Mimeographed 20pp. October 15, 1965
Variation in wood properties of water tupelo (Nyssa aquatica L.). R. L. McElwee and J. B. Faircloth. Submitted to Tappi. In Manuscript

Ohio Agricultural Research and Development Center

How do fibers develop in trees? D. K. Dougall. Ohio Report, Sept.-Oct. 1965

Oregon State University

Variation and heritability of wood specific gravity in 46-year-old Douglas-fir from known seed sources. Proc. Third Tappi Forest Biology Conference. In Press. 1965

Pennsylvania State University

The representativeness of small forested experimental watersheds in Northeastern United States. W. E. Sopper and H. W. Lull. Internat'l Assoc. Sci. Hydrol. Pub. 66(2):441-456. 1965
Streamflow characteristics of physiographic units in the Northeast. W. E. Sopper and H. W. Lull. Water Resources Research 1:115-124. 1965
The effects of harvesting forest products on water yields in Appalachia. H. W. Lull and W. E. Sopper. Soc. Amer. For. Proc. In Press. 1965
Soil site evaluation for black cherry. D. D. Davis. M.S. Thesis. 1965

Clemson University

Use of X-ray photographs for examining seed embryos. Plant Science News, Dept. of Agronomy and Soils, Clemson University. July 1964
X-ray photography as a means of examining seed embryos of forest tree species. Agricultural Research, S. C. Agr. Exp. Sta. Fall-Winter, 1964-65
A cost analysis of selected rubber-tired skidders. In Press

Texas A&M University

Oak decline in Texas. Robert S. Halliwell. Phytopathology 55:1060. 1965
Association of Cephalosporium with a decline of oak in Texas. Plant Disease Reporter. In Press.

University of Vermont

Christmas tree silviculture in New England. Maxwell L. McCormack, Jr. Amer. Christmas Tree Growers Jour. Nov. 1965

The Green Mountains as a planning region. Frederic O. Sargent and James G. Sykes. In Manuscript. 1965
A scenery classification system. Frederic O. Sargent. Jour. Soil and Water Conserv. In Press. 1966

Virginia Polytechnic Institute

An economic critique of the traditional forest regulation model. Emmett F. Thompson. Jour. Forestry. In Press
The correlation of site index of yellow poplar to soil mapping units in southwestern Virginia. Jour. Forestry. In Press

Washington State University

Use of elementary stress wave theory for prediction of dynamic strain in wood. Larry D. Bertholf. Bull. 291, Washington State University College of Engineering, Research Division. 1965
Measurement of the elasticity of lumber with longitudinal stress waves and the piezoelectric effect of wood. William L. Galligan and Richard W. Courteau. Second Symposium on the Nondestructive Testing of Wood, Madison, Wisconsin. In Press
Notes on the conidial stage of Hypoxylon fuscum. J. D. Rogers. Mycologia 57. In Press. 1965

University of Wisconsin

Effects of environment on oak wilt development. D. R. Houston, C. R. Drake, and J. E. Kuntz. Phytopathology 55:1114-1121. 1965
Diseases of Quercus in the United States. J. E. Kuntz. Diseases of Widely Planted Forest Trees, pp. 184-213. FAO/IUFRO, Symposium on Internationally Dangerous Forest Diseases and Insects. FAO/FORPEST 64. Rome. 1964
Vascular wilt diseases of forest and shade trees. J. E. Kuntz. FAO/IUFRO Symposium on Internationally Dangerous Forest Diseases and Insects. Oxford. 8pp. 1964
Translocation and persistence of cycloheximide and oligomycin in northern pin oaks. W. R. Phelps and J. E. Kuntz. Forest Science 11:354-359. 1965
Let's control oak wilt. G. L. Worf and J. E. Kuntz. Univ. Wis. Ext. Serv. Circ. 562. 1964
Preliminary investigation of the influence of photoperiod and temperature on the development of multivoltine populations of Neodiprion rugifrons Middleton. Lon L. King. M.S. Thesis. 1965
The taxonomy of Neodiprion rugifrons Midd. and N. dubiosus Schedl in the virginianus complex. G. C. Becker, R. C. Wilkinson and D. M. Benjamin. Annals Ent. Soc. Amer. In Press. 1965

PROVISIONS OF THE ACT AUTHORIZING THE
McINTIRE-STENNIS PROGRAM, REGARDING PURPOSE,
ELIGIBILITY, CERTIFICATION, APPROPRIATION, MATCHING
FUNDS AND SCOPE OF INCLUDED RESEARCH

Public Law 87-788
87th Congress, H. R. 12688
Approved October 10, 1962

An Act

76 STAT. 806, 807

To authorize the Secretary of Agriculture to encourage and assist the several States in carrying on a program of forestry research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it is hereby recognized that research in forestry is the driving force behind progress in developing and utilizing the resources of the Nation's forest and related rangelands. The production, protection, and utilization of the forest resources depend on strong technological advances and continuing development of the knowledge necessary to increase the efficiency of forestry practices and to extend the benefits that flow from forest and related rangelands. It is recognized that the total forestry research efforts of the several State colleges and universities and of the Federal Government are more fully effective if there is close coordination between such programs, and it is further recognized that forestry schools are especially vital in the training of research workers in forestry.

Sec. 2. In order to promote research in forestry, the Secretary of Agriculture is hereby authorized to cooperate with the several States for the purpose of encouraging and assisting them in carrying out programs of forestry research.

Such assistance shall be in accordance with plans to be agreed upon in advance by the Secretary and (a) land-grant colleges or agricultural experiment stations established under the Morrill Act of July 2, 1862 (12 Stat. 503), as amended, and the Hatch Act of March 2, 1887 (24 Stat. 440), as amended, and (b) other State-supported colleges and universities offering graduate training in the sciences basic to forestry and having a forestry school; however, an appropriate State representative designated by the State's Governor shall, in any agreement drawn up with the Secretary of Agriculture for the purposes of this Act, certify those eligible institutions of the State which will qualify for assistance and shall determine the proportionate amounts of assistance to be extended these certified institutions.

Sec. 3. To enable the Secretary to carry out the provisions of this Act there are hereby authorized to be appropriated such sums as the Congress may from time to time determine to be necessary but not exceeding in any one fiscal year one-half the amount appropriated for

Federal forestry research conducted directly by the Department of Agriculture for the fiscal year preceding the year in which the budget is presented for such appropriation. Funds appropriated and made available to the States under this Act shall be in addition to allotments or grants that may be made under other authorizations.

Sec. 4. The amount paid by the Federal Government to any State-certified institutions eligible for assistance under this Act shall not exceed during any fiscal year the amount available to and budgeted for expenditure by such college or university during the same fiscal year for forestry research from non-Federal sources....

Sec. 7. The term "forestry research" as used in this Act shall include investigations relating to: (1) Reforestation and management of land for the production of crops of timber and other related products of the forest; (2) management of forest and related watershed lands to improve conditions of waterflow and to protect resources against floods and erosion; (3) management of forest and related rangeland for production of forage for domestic livestock and game and improvement of food and habitat for wildlife; (4) management of forest lands for outdoor recreation; (5) protection of forest land and resources against fire, insects, diseases, or other destructive agents; (6) utilization of wood and other forest products; (7) development of sound policies for the management of forest lands and the harvesting and marketing of forest products; and (8) such other studies as may be necessary to obtain the fullest and most effective use of forest resources.

Sec. 8. The term "State" as used in this Act shall include Puerto Rico.

* * * * *

Additional information about the McIntire-Stennis Program is given in the Fact Sheet on the McIntire-Stennis Cooperative Forestry Research Program, Cooperative State Research Service, U. S. Department of Agriculture CSRS-OM-3256, November, 1965. Copies are available from the Assistant Administrator, Cooperative Forestry Research, CSRS.

